Alternative Sources of Sand and Gravel for Niagara

C. MIRZA ENGINEERING INC.
GEOTECHNICAL SPECIALISTS

Regional
NIAGARA

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EXECUTIVE SUMMARY

Background

The Fonthill Kame in the Town of Pelham, Ontario represents, at present, the only significant land-based source of sand and gravel in the Niagara Region. Its current annual production is about 500,000 tonnes per year which satisfies about 80 to 90 percent of the Regional demand for sand and gravel.

The area surrounding the Fonthill Kame is dedicated to tender-fruit growing. Present exploitation of the sand and gravel resources from the Kame and possible future expansion of extraction activities is being viewed with increasing alarm by the environmentally-conscious and the residents of the Town of Pelham.

In order to address the problem of securing an adequate supply of aggregate products for Regional developmental needs on the one hand, as well as maintaining an acceptable rural, agrarian and urban environment and quality of life on the other, the Regional Municipality commissioned a Study to investigate alternative sources to the Fonthill Kame.

The Consulting Engineering firm of C. Mirza Engineering Inc. was retained to perform certain tasks in that Study. This Report presents the findings of those tasks, and incorporates these findings with those of other tasks performed by the Region and the University of Guelph.

Study Scope

The Study terms of reference were outlined by the Region prior to its commencement and were detailed by mutual discussions between the Region and the Consultant.

In broad terms, the Study goals were:

1) To establish the demand potential for all types of aggregate resources in the Region to the year 2000 and beyond.

2) To examine the feasibility of replacing current and future Kame production with products from alternate sources including:

   a) Dredged sand from the Niagara Bar, located near the mouth of the Niagara River and other near shore deposits in lake Erie.

   b) Replacement potential for crushed stone and manufactured sand from quarries.

   c) Land-based sources in the Region other than the Fonthill Kame.

d) Importation of aggregates into the Region from surrounding jurisdictions within Ontario and the U.S.

e) The effect of recycling, substitution of waste products and new technologies in construction on future aggregate requirements.

Study Findings

The Study methods used to forecast demand for aggregate products are given in detail in Chapter 2 of this Report. Based on current economic trends, it was estimated that some 60 million tonnes of all types of aggregates would be required to the end of this century to satisfy the Regional demand.
A major portion (over 40 million tonnes) of the total cumulative demand will be met by quarry production, which now satisfies the needs for most clear aggregates, granular base and subbase and other coarse aggregates.

At present, the only product critically dependent on the Kame source is concrete sand, which is used as a fine aggregate in ready-mix and other types of concrete products (bricks, blocks etc.). The total cumulative demand for concrete fine aggregates (including concrete sand, screenings, dredged sand) in the Region was forecast at about 8.1 million tonnes by the end of this century. In 1984, the concrete sand production from licensed Kame areas was over 0.2 million tonnes in the Region.

Early in this Study, it was recognized that many of the current products from the Kame operation could be replaced by alternate sources without adversely affecting Regional needs for these products. The one critical area which required further study was the one dealing with concrete sand. The present and potential future abundance of concrete sand in the Kame has inhibited the development and deployment of alternative concrete sand sources and/or replacement products in the Region. Therefore, one of the aims of this Study was to concentrate on the feasibility of satisfying concrete fine aggregate demands on the Region from sources other than the Kame.

The Niagara Bar is being exploited to a modest degree at this time, with an annual production of some 45,000 tonnes of concrete sand, most of which is presently shipped to Hamilton where it is used as a fine aggregate component in ready-mix. Testing by reliable governmental agencies indicated that this sand when used alone was unsuitable for most concrete applications.

In Chapter 3 of this Report, the Niagara Bar potential was examined in detail. There is no doubt that additional research and testing are required to more positively quantify the potential reserves and to assess their quality for use as concrete sand. This Study estimated a potential supply of over 6 million tonnes of gradationally acceptable concrete sand from the Niagara Bar. However, this quantity is attainable only by certain blending operations within the Bar area. Such a large potential reserve of concrete sand can serve the needs of the Region well into the next century. The deployment of this potential reserve, however, would require land-based operational investments and expansions, which are detailed in Chapter 3.

The Niagara Bar sand, after blending to an acceptable gradation, might still prove unacceptable from a quality viewpoint due to the presence of deleterious substances such as chert. Hence, this sand would need either to be extensively beneficiated or blended with a sand manufactured from quarried materials (or Fonthill sand for that matter) to make it generally acceptable to industry and consumers.

Manufactured sand as a quality-controlled, processed, fine aggregate produced from quarried stone was studied and discussed in detail in Chapter 4. Essentially, the current problem with the use of manufactured sand in concrete products is the decreased workability of the mix which must be overcome through additives and the increased use of cement which increases the cost of concrete produced from manufactured sand. Part of this problem can be overcome by advanced crushing techniques. The technology to produce manufactured sand is well known, however the general abundance of concrete sand has prevented the development of a manufactured sand industry in the Region. Wholesale replacement of natural sand by a manufactured product is not likely to occur overnight. Much research is needed before general acceptance of the product prevails in the marketplace.

The results of a study conducted by the Regional Municipality on land-based sources of sand and gravel in the Niagara Region is given in Chapter 5. Essentially, no significant source of concrete sand was identified within the Regional boundary. However abundant supplies of concrete sand are present outside the Reigon particularly in the Brantford-Paris and Cambridge areas to the west. In addition, concrete sand is available from Erie, Pennsylvania to the south. Hence, the economics of importing these products into the Region was studied and is reported in Chapter 6. It is concluded that importation of concrete sand into the Region would entail an increased delivered price (weighted average throughout the Region) of about $2.25 above current Fonthill prices for the Erie, Pa. sand and $2.70 a tonne more when imported from the Brantford-Paris area.

Emerging technologies which may reduce the demand for aggregates were studied and are reported in Chapter 7. In addition, substitute materials, such as slag, were evaluated. The impact on aggregate consumption of recycling asphalt pavements, substitution of slag, or using foundry sand from the GM plant in St. Catharines was found to be marginal.

Study Conclusions

The chief conclusion of this Study is that the entire Regional demand for all types of aggregate products to the year 2000 and beyond can be met by sources other than the Fonthill Kame. As pointed out earlier, the Fonthill Kame is at present a crucial source of concrete sand in the Region. It cannot be replaced overnight due to limitations arising from a lack of reliable data on the Niagara Bar potential and the emerging stages of manufactured sand technology. The details of these problems are given in Chapters 3 and 4 respectively and are summarized in Chapter 8.

There are broad socio-economic implications involved in any policial decision as to the future disposition of the Kame which are beyond the terms of reference of this Study. However, should a decision be taken to curtail extraction operations in the Kame area based on the results of this Study, several implications should be weighed and evaluated.

1) Alternative sources, products and technologies are not fully developed at this stage to satisfy current or future demand for aggregate products in the Region.

2) The development and deployment of these alternative resource bases will require in-depth investigations, research and economic studies such as:

   - Quantification of Niagara Bar reserves by detailed site investigations
   - Research into the quality of Bar sand alone and when mixed with manufactured sand (or screenings) for use in concrete.
   - economic studies of expanding the present dredging operations, docking facilities, constructing beneficiating plants and the like to take advantage of the large potential of the Bar.
   - Research into the production facility requirements for manufacturing sand from quarried rock in the Region.

If the Kame operations are phased out over a period of time, then shortfalls, particularly in concrete sand supply, could be made up by importing into the Region, at a substantial premium price above that now commanded by Fonthill.

Finally, the environmental impact of increased dredge production from the Bar should be evaluated as well as the public acceptance of increased truckage and road use cost if substantial quantities are imported into the Region.

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GLOSSARY OF TERMS

Absorption - A measurement of an aggregates' ability to absorb water. For a certain volume of aggregate, its absorption is given by (mass in its saturated surface-dry condition minus its dry mass) divided by its dry mass.

Air - Entraining Agent - An additive which increases the workability and the resistance of concrete to frost action by introducing numerous tiny air bubbles into the hardened cement paste.

Alkali-Carbonate Reactivity - A chemical reaction between aggregates composed of some argillaceous, dolomitic limestones and calcidic dolostones containing metastable dolomitic and possibly cryptocrystalline calcite and the alkalies in the cement within concrete.

Alkali-Silica Reactivity - A chemical reaction between silica (in sandstones and granites) in aggregates and the alkalies in the cement within concrete. An alkali-silica gel is formed,which on expansion causes generation of internal stresses and subsequent expansion and disruption of concrete.

Anthropogenic - Generated by human activities

Aphanatic - Pertaining to the texture of rocks in which the crystalline constituents are too small to be distinguished by the unaided eye.

Argillaceous - Applied to all rocks or substances composed of clay minerals, or having a notable proportion of clay in their composition, as shale, slate etc.

Avulsed - Related to rapid abandonment of the river channel.

Bathymetric - Relating to measurements of depth; usually applied to an ocean or lake.

Bed Load - Soil, rock particles or other heavy debris transported at the bottom (near the bed) of fluid flows, either of the river or longshore currents.

Beneficiation - To improve the grade of aggregates by proportionally reducing the amount of potentially deleterious materials.

Bioclasts - Broken skeletal remains of dead organisms.

Bioherme - Domelike, moundlike or lenslike mass built exclusively or mainly by sedentary organisms such as corals, stromatoporoids, algae etc. and enclosed in a normal rock of different lithological character.

Biostrome - A bedded structure composed of shell beds, crinoid beds, coral beds etc., which was built by sedentary organisms grown and preserved in place.

Bituminous - Contains various inflammable mineral substances mainly of hydrocarbons.

Calcareous - Containing calcium carbonate.

Chalcopyrite - A brass-yellow copper iron sulphide mineral with a metallic lustre enlivened by a reddish and bluish iridescence.

Chert - A cryptocrystalline variety of quartz composed of interlocking grains generally not discernible under a low-powered microscope.

Clastic Sediment - The accumulated particles of broken rock and or skeletal remains of dead organisms.

Coefficient of Thermal Expansion - A measure of the tendency of a material to change size when subjected to a change in temperature.

Concrete or Concrete Products - In the context of this Report, this term refers to any product made using aggregates, water and Portland Cement. This includes ready-mix, bricks, blocks, pipes etc.

Concrete Sand - In the context of this Report, this term will only be used to describe naturally sorted aggregates from land-based pits or dredging which can be used as the fine component for any concrete product (including ready-mix, bricks, blocks etc.). Although some crushing may be involved, this term will not be used to refer to particles formed exclusively by the crushing of rock.

Conformity - Boundary between two rock layers deposited in succession.

Contact (Between two Rock Units) - A surface along which two rock units meet.

Crinoidal - Containing compact, cup-shaped aquatic organisms (crinoids) composed of symmetrically-arranged calcareous plates.

Crushed Stone - In the context of this report, this will refer to any gravel and cobble-sized particles produced exclusively by crushing rock.

Disconformity (Disconformable) - Unconformity between parallel strata; with strata below not dipping at an angle to those above.

Distributary Mouth Bar - Accumulation of granular material at or near the mouths of rivers discharging into large bodies of water, like seas or lakes. The deposit can be formed by material transported by the river, or by longshore current or both.

Evaporite - A nonclastic sedimentary rock whose constituent minerals were precipitated from water solution as a result of evaporation.

Facies - A distinctive group of characteristics, within a rock unit, that differ as a group from those elsewhere in the same unit.

Fine Concrete Aggregates - In the context of this Report, this term will refer to any aggregate material used as the fine component for any and all concrete products (including bricks, ready-mix, blocks etc.). This includes concrete sand, manufactured sand, screenings, flyash etc.

Fissility - A property of splitting easily along closely-spaced parallel planes.

Frequency Distribution - An arrangement of data which subclasses the possible values of a variable into categories or intervals.

Glauconite (Glauconitic) - A green mineral closely related to the micas and essentially a hydrous aluminosilicate of iron, magnesium and potassium. It is an important constituent of marine sediments.

Gyre - Refers to a spiral-like movement of water and material transported in a bay or part of a large body of water such as a lake.

Hematite - An earthy, fibrous or metallic iron oxide mineral, black or red in colour.

Ice-Contact Stratified Drift - Stratified drift deposited in contact with its support ice.

Income Rating Index - The disposable income per capita in a Region as a percentage of Ontario's income per capita.

Interstadial - Refers to short non-glacial periods during major glaciations when an area was free of glacier ice and received water-laid or wind-blown sediments.

Interstitial - Within the gaps between grains of sediments or rocks.

Kame - A conical hill or short irregular ridge of gravel or sand deposited in contact with glacier ice.

Kurtosis - A statistic which measures the ratio between the sorting of the 'tails' of a curve fitting the frequency distribution of measured values and the sorting of the central portion. If the central portion is better sorted than the tails, the curve is said to be excessively peaked or leptokurtic; if the tails are better sorted than the central portion, the curve is deficiently or flat-peaked and referred to as platikurtic.

Lag Deposit - A residual accumulation of coarser particles from which the finer material has been washed (or blown) away.

Liable - In the context of this Report, this term refers to materials and minerals which may break down or react with other substances when used under particular conditions. This term is preferred to its synonymous 'deleterious' because liable connotes an innate property of the deposit, independent of its use.

Lithology (Lithological) - The physical character of a rock, generally as determined megascopically or with the aid of a low-power magnifier.

Lithographic (Sublithographic) Limestone - A very fine-grained precipitated limestone.

Load (of a stream) - The material carried at a given time, by a stream, by a current of water, by the wind or by a glacier.

Longshore Current - A current, within the surf zone, that parallels to the shore.

Los Angeles Abrasion - A measurement of the hardness of aggregates. The aggregate to be tested is prepared and placed in a drum with a number of steel balls. The drum is rotated a specified number of times and the loss of material is measured.

Loss On Ignition (LOI) - Loss of weight of samples when heated to 1050 degrees centigrade, generally due to loss of organic carbon first and mineral-bound carbon at a later stage.

Magnesium Sulphate Soundness - A measure of an aggregates' susceptibility to weathering. A sample is saturated in a solution of magnesium sulphate then removed and dried in an oven. This process is repeated 5 times and then the percentage lost or broken down is calculated.

Manufactured Sand - In the context of this Report, this term will only be used to describe a quality controlled, processed fine aggregate produced only by crushing or size reduction equipment along with mechanical (water or air) classification systems to separate out unwanted sizes.

Market Attraction Index - Market Rating Index divided by the Income Rating Index.

Market Rating Index - The retail sales per capita of a Region as a percentage of the Ontario retail sales per Capita.

Marshall Stability - A measure of the strength and flexibility of asphalt mixtures. The test measures the maximum circumferential compressive load that a sample can carry.

Micaceous - Containing mica.

Modal Analysis (Mode) - The quantitative microscopic determination of the mineralogy of a sample, generally conducted by counting a number of grains (200+) along pre-established transects in grain mounts and in thin sections.

Morphology - The observation of the form of lands.

Phi - A phi plot is an alternate method of plotting the grain size distribution of a sample. Phi is defined by the equation given by : $\phi = (\frac{1}{2})^D$ where D is the diameter of the particle in mm.

Portland Cement Concrete - In the context of this report, this term will be used interchangeably with ready-mix concrete.

Pozzolan (Pozzolanic) - A siliceous substance (fly ash or pumice) that will react with lime in the presence of water. Can be used in combination or for partial replacement of Portland cement. It provides workability with less total water, reduction in the heat of hydration and increased resistance to sulphates.

Pumpability - The ability of a concrete mixture to move under pressure in a curved pipe which causes differential internal movement of its ingredients.

Reef - A ridge of limestone built by colonial marine organisms.

Relict Deposit - In the context of this Report, this terminology refers to an accumulation of granular material formed under previously existing conditions. The deposit has been preserved essentially fossilized to the present times. It has not been reworked by modern processes other than superficially.

Sand and Gravel - In the context of this Report, this will refer to any natural accumulation of sand and gravel-sized particles deposited by ice, water etc. Although some crushing may be involved, this term will not refer to particles formed exclusively from the crushing of rock.

Skewness - It measures the degree of asymmetry (lack of symmetry) and sign in the curve of a frequency distribution. It indicates whether a curve has an asymmetrical tail on the left or right.

Stadial - Times during a glacial period when the land is covered by glaciers. The deposited materials are derived directly from glaciers.

Stratification - Layered arrangement of the particles that constitute sediment or sedimentary rock.

Sulphate Resistant Cement - A cement containing pozzolans such as flyash which cause it to become more resistant to sulphate attack.

Suspended Load - The fine solid particles turbulently suspended within a body of flowing fluid.

Transgression - This refers to the rise in water level of the lake: the shoreline moves (transgresses) landward.

Unconformity - A lack of continuity between two units of rock in contact, corresponding to a gap in the geologic record.

Vesicular - Containing small openings called vesicules. Vesicules are found in igneous rocks and are made by escaping gas orginally held in solution under high pressure while the parent magma was underground.

Vugs (Vuggy) - Open cavities in rocks, often lined with crystals.

Water/Cement (W/C) Ratio - The ratio by weight of the quantity of water to the quantity of cement used in concrete. The W/C ratio is a primary factor in determining the compressive strength of concrete.

Winnowing - The process of removing the fine fractions (silt and clay) from a granular deposit, by water flows.

CONVERSION FACTORS

1 tonne = 1.1 tons

1 ton = 0.9072 tonnes

1 cubic yard of dredged sand weighs 1.36 tonnes (1.5 tons)*

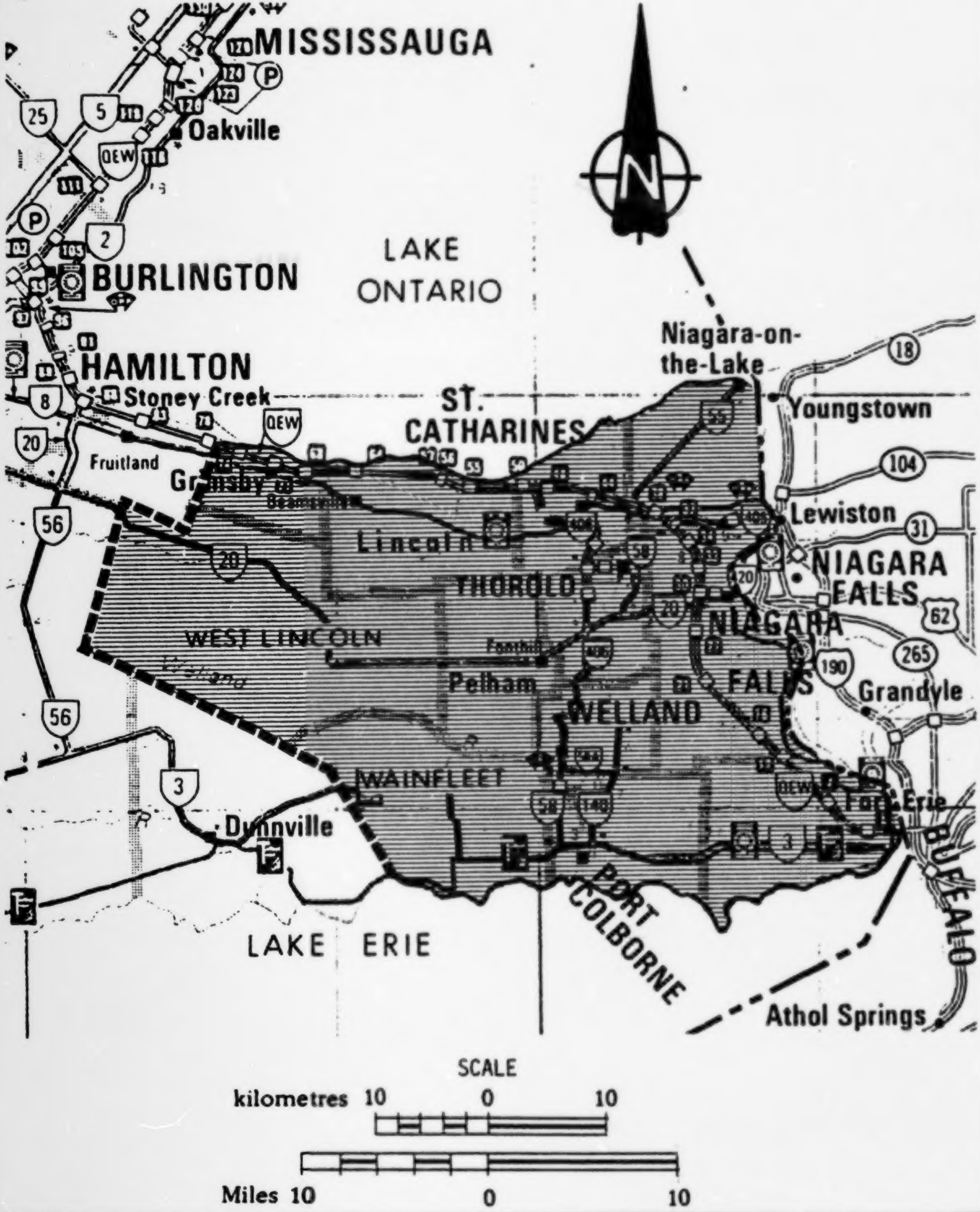
1 cubic metre of dredged sand weighs 1.54 tonnes (1.7 tons)*

1 Ha = 2.47 acres

1 $ U.S. = $ 1.39 Can.

* Note: - Specific gravity of dry sand was assumed to be 2.65.
- Information was obtained from the Regional Municipality of Niagara.

C. MIRZA ENGINEERING INC.
GEOTECHNICAL SPECIALISTS


MISSISSAUGA
Oakville
BURLINGTON
HAMILTON
Stoney Creek
Fruitland
Grimsby
Beamsville
LAKE ONTARIO
Niagara-on-the-Lake
Youngstown
ST. CATHARINES
Lewiston
NIAGARA FALLS
Lincoln
THOROLD
WEST LINCOLN
Pelham
Fonthill
NIAGARA FALLS
Grandyle
WELLAND
WAINFLEET
Dunnville
Fort Erie
PORT COLBORNE
BUFFALO
LAKE ERIE
Athol Springs
QEW
25
5
2
8
20
56
3
55
58
140
406
190
62
265
18
104
31
SCALE
kilometres 10 0 10
Miles 10 0 10

KEY PLAN
SHOWING
THE NIAGARA REGION

1.0 INTRODUCTION

1.1 Definitions

The 'Niagara Region' or 'Region' for short shall henceforth refer to the geographic area shown on the Key Plan opposite.

'Regional Niagara' shall henceforth refer to the Regional Municipality of Niagara or the governing body.

The 'Study' shall henceforth refer to the work carried out as defined by the Detailed Terms of Reference submitted to us by the Regional Municipality of Niagara.

'Concrete fine aggregates' in the context of this Report will refer to any aggregate material used as the fine component for any and all concrete products (including bricks, ready-mix, blocks etc.). This includes concrete sand, manufactured sand, screenings, etc.

For additional definitions see the GLOSSARY OF TERMS.

1.2 Terms of Reference

The Regional Niagara Planning and Development Committee selected C. Mirza Engineering Incorporated to study various 'Alternative Sources of Sand and Gravel Supply' for the Niagara Region.

The proposed Study was divided into seven fairly independent yet linked Tasks, each dealing with a specific issue. These Tasks have been defined in Report DPD 1739 included in Appendix I. All Tasks with one exception were carried out by a project team consisting of staff from C. Mirza Engineering Inc., the University of Guelph and Peat Marwick and Partners Inc. The remaining task, on an inventory of land-based sources of sand and gravel in the Region, was carried out by staff of the Planning and Development Department at the Regional office.

1.3 Definition of Problem

Succinctly stated, the essential problem was to identify other possible sources of aggregates within (or outside of) the Region which could replace products currently being produced by operators on the Fonthill Kame, with particular emphasis being put on concrete sand.

A number of alternatives were considered including:

1) Dredged materials from the Niagara Bar, the Niagara River and Lake Erie
2) Crushed stone and manufactured sand from quarries

3) Other land-based sources of natural sand and gravel within the Region
4) Importation of materials

In addition, recycling, substitution and new construction technologies were evaluated as to how they may affect the supply / demand scenario of aggregates in the Region.

The problem and purpose of the Study is synthesized in Figure 1.1.

1.4 Scope of Problem

As shown in Figure 1.1, the Study starts with the determination of future demand for aggregate products within the Region. Each of the various alternative sources were then considered; first singly; then in combination as to their ability to satisfy demand for some or all aggregate product types, with particular emphasis on concrete sand. Aggregates from each source were evaluated on the basis of quality as well as available quantity. Other factors or constraints were dealt with in more general terms.

1.5 Background to Study

Southern Ontario has huge reserves of sand and gravel which serve a wide range of uses in road and building construction as well as concrete products. Although the total resources are large, there is often great disparity between supply and demand within a particular region. This is due to a variety of factors including:

1) Population patterns
2) Agricultural, environmental and other constraints
3) Distance between source of aggregate and area of consumption
4) Economic factors (including, supply, demand, transportation, investment climate, etc)

The Niagara Region is fairly well-endowed with suitable raw materials for many crushed stone products (total unlicenced reserves outside of urban areas and the Niagara Escarpment Development Control Area are estimated at 6.1 billion tonnes (see Section 4.6 for details)) but it is lacking in adequate supplies of sand and gravel which are required for high quality products such as concrete sand.

There are a number of presently licensed pits and quarries operating in the Region. The locations of these are shown in Figure 1.2 and on Drawing No's 1 and 2 in the pocket at the back of this Report. By far the largest producers of land-based sand and gravel within the Region are located near Fonthill in the Town of Pelham. The so-called Fonthill Kame deposit produces most (currently about 80 percent) of sand and gravel mined in the Region per year and represents nearly all of the selected reserves. The importance of this deposit from an aggregate supply standpoint is therefore quite clear.

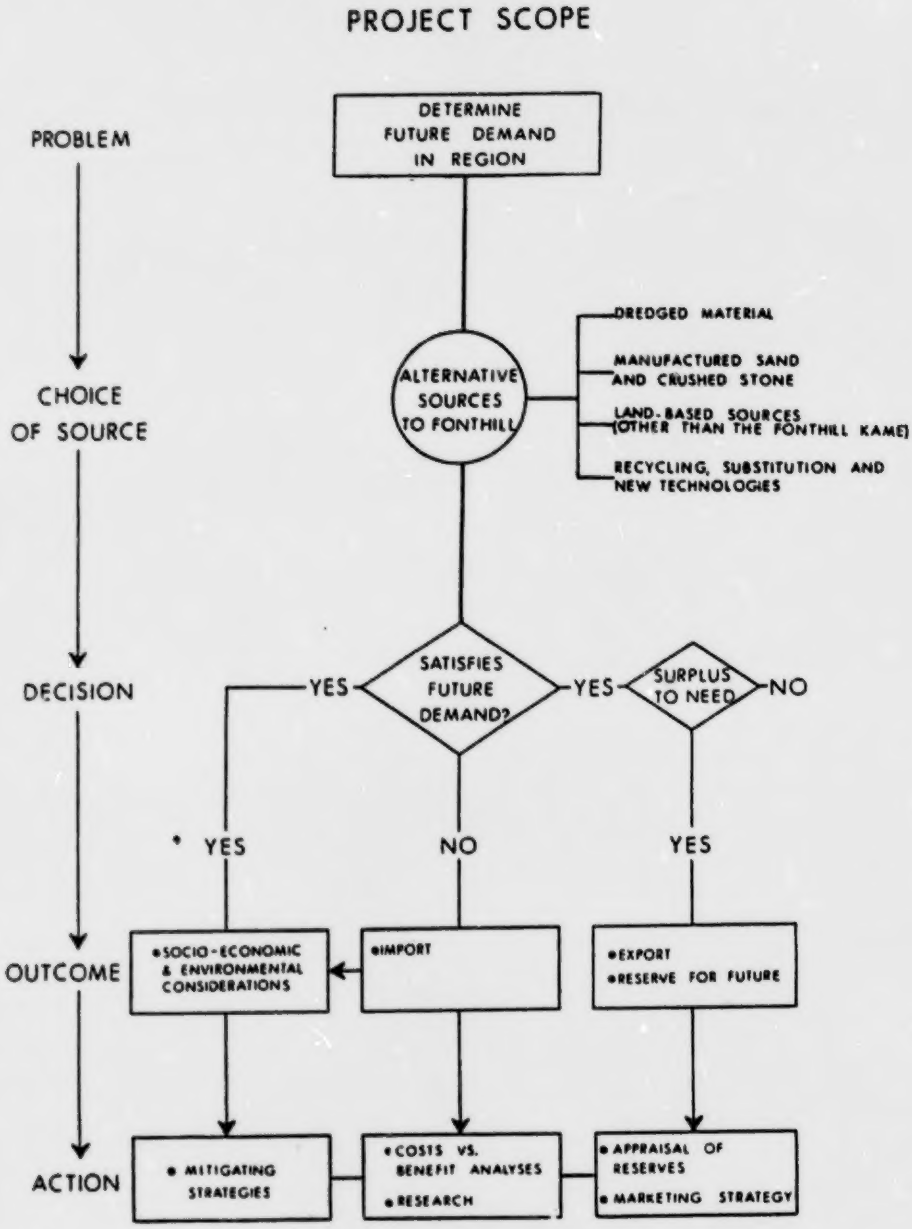

PROJECT SCOPE
PROBLEM
CHOICE OF SOURCE
DECISION
OUTCOME
ACTION
DETERMINE FUTURE DEMAND IN REGION
ALTERNATIVE SOURCES TO FONTHILL
DREDGED MATERIAL
MANUFACTURED SAND AND CRUSHED STONE
LAND-BASED SOURCES (OTHER THAN THE FONTHILL KAME)
RECYCLING, SUBSTITUTION AND NEW TECHNOLOGIES
SATISFIES FUTURE DEMAND?
YES
YES
SURPLUS TO NEED
NO
YES
NO
YES
•SOCIO-ECONOMIC & ENVIRONMENTAL CONSIDERATIONS
•IMPORT
•EXPORT
•RESERVE FOR FUTURE
• MITIGATING STRATEGIES
•COSTS VS. BENEFIT ANALYSES
•RESEARCH
• APPRAISAL OF RESERVES
• MARKETING STRATEGY

Figure 1.1 - Schematic Diagram Representing the Scope of the Study

LICENSED SAND AND GRAVEL PITS

1. St. David's Sand and Gravel Pit No. 1 (Walker Bros.)
2. St. David's Sand and Gravel Pit No. 2 (Walker Bros.)
3. Calaguiro Bros. Sand and Gravel.
4. Allan's Halfway Sand Pit Ltd.
5. Moyer Sand, Steed and Evans Ltd.
6. T.C.G. Materials Ltd.
7. D.L. Stephens Contracting Niagara Ltd.
   (Formerly the Bishop Pit)
8. Hard Rock Paving Co. Ltd.
9. Mr. A. Eberly (c/o Sherkston Beach Ltd.)

LICENSED SAND DREDGING.

10. McKeil Work Boats Ltd.
    Note - 3 Licensed areas

LICENSED QUARRIES

11. Nelson Aggregates Ltd.
12. Clinton Quarries Ltd. (Walker Bros.)
13. Vineland Quarries Ltd., Quarry No. 1 (Walker Bros.)
14. Vineland Quarries Ltd., Quarry No. 2 (Walker Bros.)
15. Walker Bros. Quarries Ltd.
16. Queenston Quarries Ltd.
17. Ridgemount Quarries Ltd. No. 2 & 3 (Walker Bros.)
18. Ridgemount Quarries Ltd. No. 1 (Walker Bros.)
19. Port Colborne Quarries Ltd.
20. R.E. Law Crushed Stone Ltd. (Hard Rock Paving Co. Ltd.)

Legend for Figure 1.2 shown on opposite page

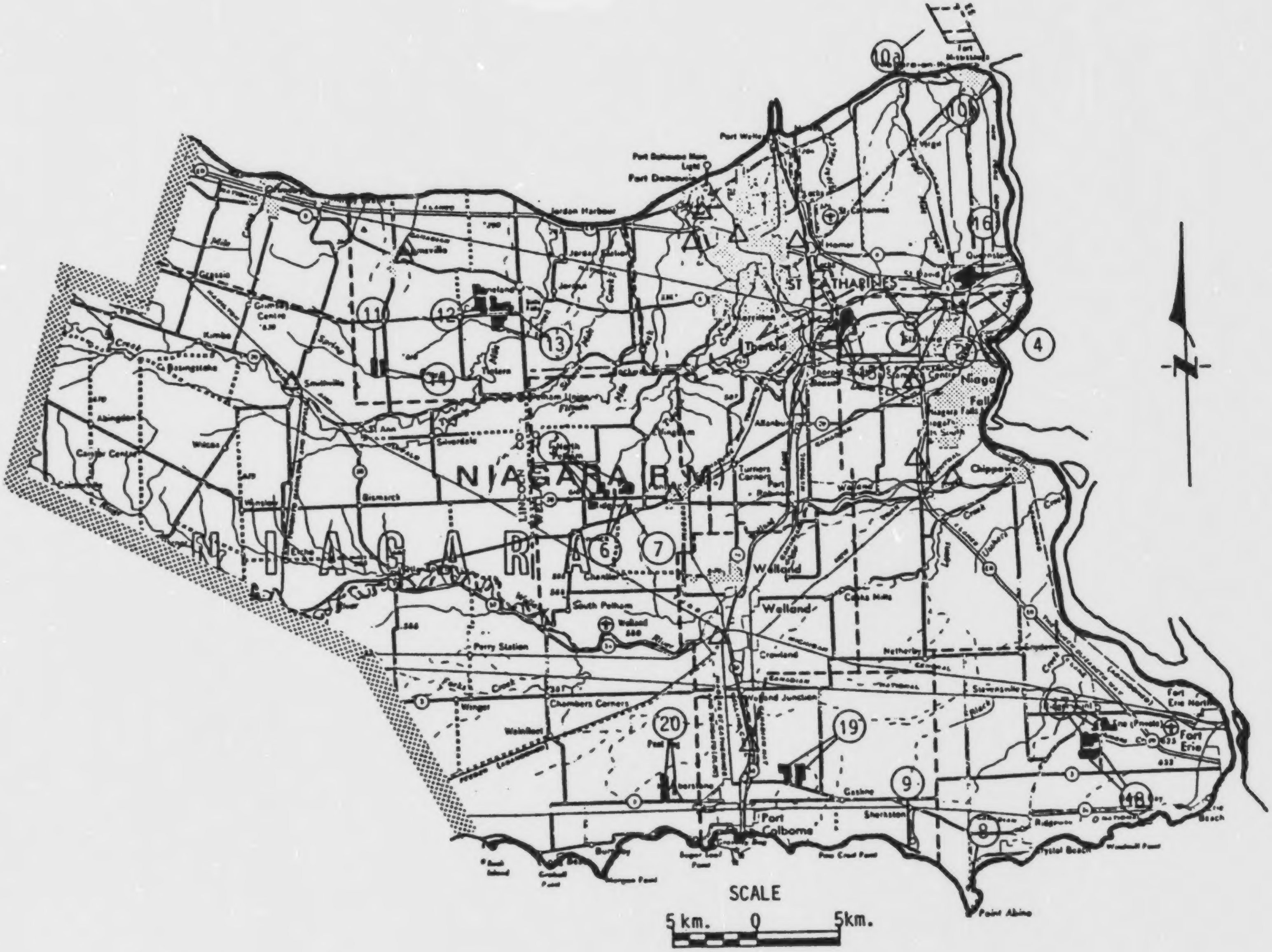

10a
10b
16
4
1
2
11
12
13
14
5
6
7
15
20
19
9
8
18
NIAGARA R.M.
NIAGARA
ST CATHARINES
Thorold
Niagara Falls
Welland
Port Colborne
Fort Erie
Jordan Harbour
Port Dalhousie
Chippawa
Queenston
Point Abino
SCALE
5 km.
0
5km.
N

Figure 1.2 - Licenced Pits and Quarries in the Niagara Region. See opposite page for legend.

Due to the nature and location of the Fonthill Kame, there is increasing pressure from many sources to lessen the impact of production from this source. Some of the reasons cited for possibly halting further development and utilization of the Fonthill Kame are:

1) It is a very significant tender fruit growing area (Regional Niagara Planning and Development Department, 1984).

2) It is important for environmental, scenic and recreational purposes (Regional Niagara Planning and Development Department, 1984).

Even if production on the Kame remained equal to present rates, the remaining licenced resources would be depleted in 3 to 4 years. Therefore, it is necessary to find alternative sources wherever possible. Each of the alternatives being considered is dealt with in Chapters 3 to 6 of this Study.

1.6 Aggregate Production in the Region

Figure 1.3 shows the production of aggregates from each source in the Niagara Region. This shows that production from all sources has generally declined during the last decade and a half from a high of approximately 6.7 million tonnes in 1972 to about 4.7 million tonnes in 1984.

Quarries have been the largest aggregate producers in the Niagara Region. They currently represent roughly 3.4 million tonnes or 86 percent of the total aggregates (Figure 1.4) produced in the Region. Although total production of all aggregates has generally declined, the proportion of aggregates represented by quarries has been slowly increasing during the last decade and has levelled off at about 82 percent.

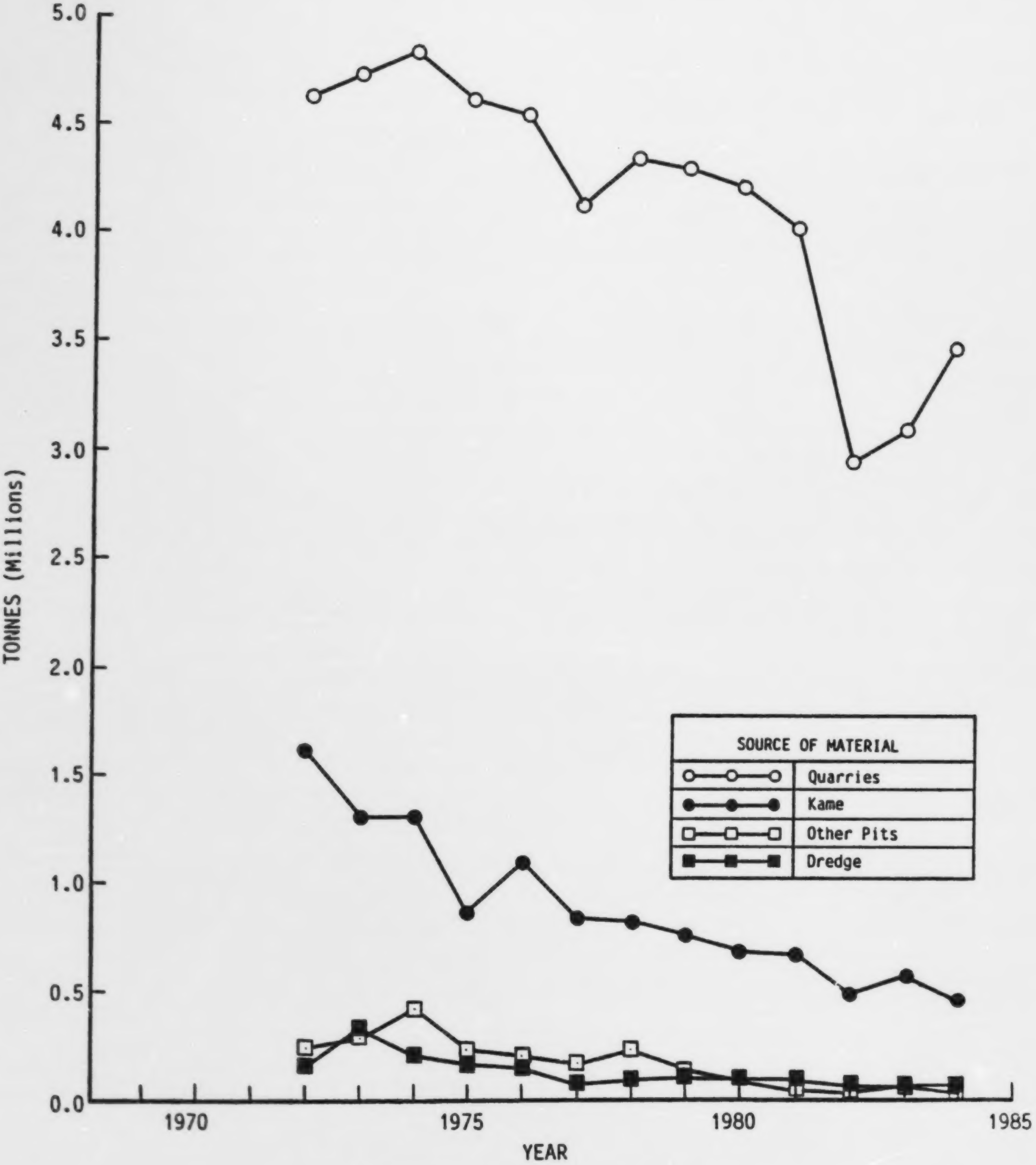
The largest producer of sand and gravel in the Region by far has been the Fonthill Kame. Today, the Kame produces about 0.5 million tonnes or 80 percent of the sand and gravel produced in the Region. Dredging and other land-based pits together produce about 200,000 tonnes or less than 5 percent of the total aggregates (and 20 percent of the sand and gravel) produced in the Niagara Region.

1.7 Aggregate Specifications

The suitability of material from any alternative source is dependent upon many factors; foremost being the quantity and quality of the reserves available. Both of these criteria will be dealt with in greater detail in Chapters 3 to 6.

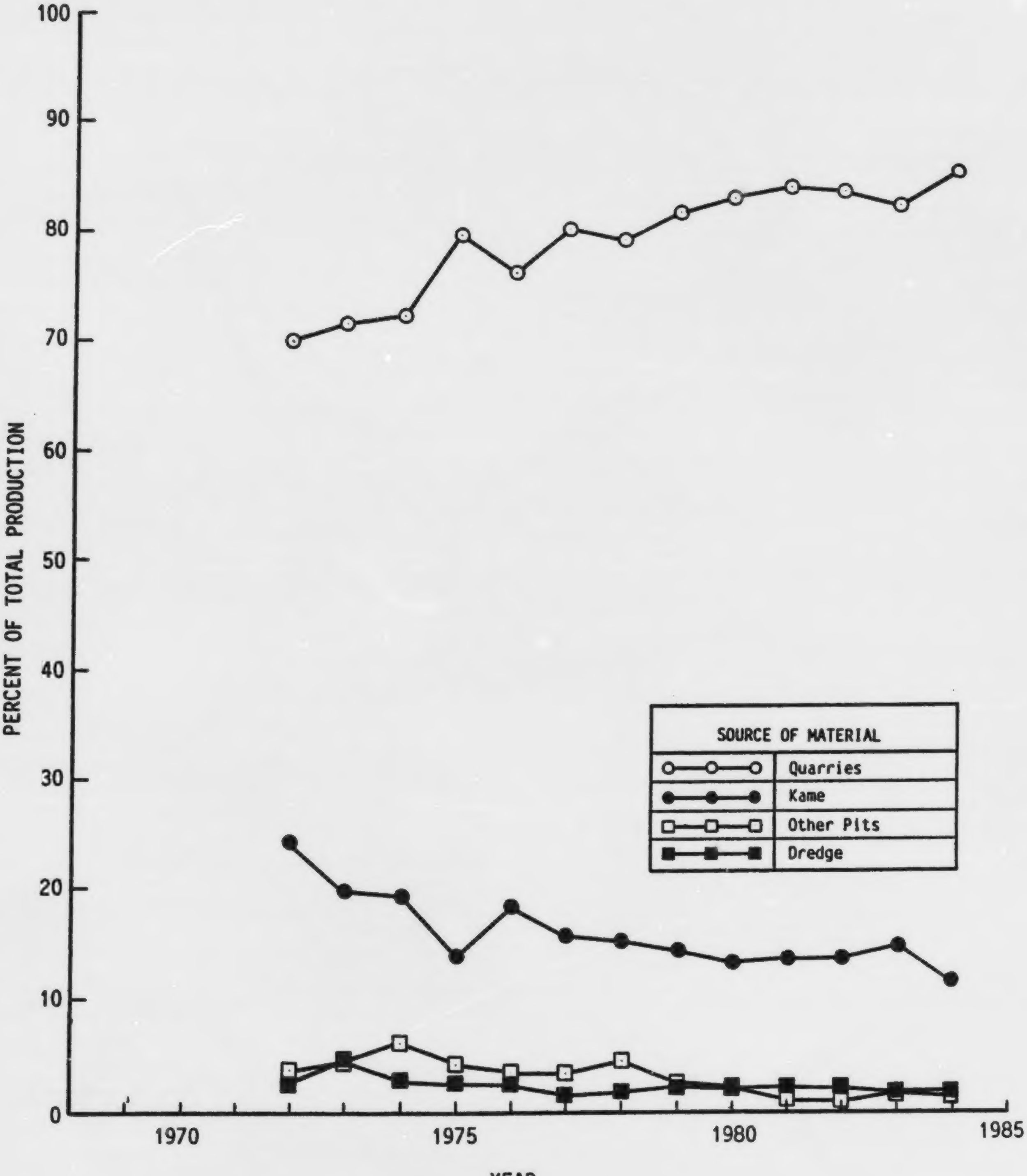
The quality of aggregate products used in Ontario has been specified by a number of organizations including:

1) The Aggregate Producers Association of Ontario (APAO)
2) The Canadian Standards Association (CSA)



PRODUCTION OF AGGREGATES BY SOURCE
(Total Production in Tonnes)

Figure 1.3



PRODUCTION OF AGGREGATES BY SOURCE
(Percentage of Total)
Figure 1.4

3) The American Society for Testing and Materials (ASTM)
4) The Ministry of Transportation and Communications (MTC)
5) The Canadian National Railway (CNR)
6) The Canadian Pacific Railway (CPR)
7) The American Railway Engineering Association (AREA)

It has been found that aggregate products can be grouped into five major categories including:

1) Granular Base and Subbase
2) Coarse Aggregate
3) Fine Aggregate
4) Clear Aggregate
5) Special Applications Products (Armour Stone, Mineral Filler, Slurry Seal etc.)

Detailed specifications for the various aggregate products under each of these five main groups is shown in the charts given in Appendix II.

2.0 AGGREGATE DEMAND PROJECTIONS FOR THE NIAGARA REGION

2.1 Introduction

The Fonthill Kame is presently the major producing source of sand and gravel within the Niagara Region. Other licenced land-based sources have provided some additional quantities of natural aggregates (less than 50,000 tonnes) in the past but this has been much less than the Kame presently supplies which amounts to about 0.5 to 0.6 million tonnes/year.

If the Fonthill Kame ceases operation, other sources of aggregates such as dredged materials and manufactured sand (from quarries) may be able to supplement or replace most natural aggregates, provided that they are of suitable quality and it is economically justifiable to do so. These other alternatives are discussed in detail in the remaining chapters.

On the other hand, some aggregate products currently being supplied from Fonthill may have few presently viable alternatives. For example, most major users of concrete presently require that some natural sand be used for ease of workability. Therefore, the question may be asked that if production of aggregates from the Fonthill Kame was eventually phased out, would other sources be able to provide the amount and as well as the quality of natural aggregates required for such products? This means that the supply/demand scenario for certain natural aggregates is a very important consideration when decisions are being faced regarding land use policy on the Kame.

2.2 Demand Forecasting Models

Several models have been developed in the past for forecasting the future demand for sand and gravel within various regions in Ontario (see Matten, 1982; Kearney and Elek, 1981; Regional Niagara, 1981 and Hertzberg, 1976). Most of these models depend to a large extent on forecasting construction expenditures since expenditures are directly related to aggregate consumption through so-called 'input factors'. These input factors which are stated, for example, in tonnes per constant 1971 dollar, have been statistically derived and are assumed to be valid over the forecast period.

Forecasting is not an exact science since all predictions require a number of assumptions. The accuracy of the forecast depends upon how accurately those assumptions represent the true situation.

Several forecasting models were studied to determine their applicability to the project at hand. Three of them were studied in detail including those by:

1) The Ministry of Natural Resources (Matten, 1982)
2) The Regional Municipality of Niagara (Regional Niagara, 1981)
3) Peat Marwick and Partners (Elek, 1980)

2.2.1 The Ministry of Natural Resources Model (Matten, 1982)

The methodology of the model developed by the Ministry of Natural Resources was studied in detail. This model is described by Matten (1982):

'The developed and tested model uses the Gross Provincial Product per capita which after adjustment by market and income rating indices, that measure the pull of the economic regional market, indicates the gross income per capita in the region. This gross income per capita multiplied by the number of residents in a region produces its gross regional product.'

A calculated ratio of construction expenditures in Ontario to Gross Provincial product is applied to the gross regional product and modified by an average Market Attraction Index, developed for each region, to yield the total construction expenditure in the region'.

Here, region is being used to describe, for example, the Central Ontario region of which the sub-region of Niagara (or Niagara Region in most sections of this Report) is a part. The construction expenditures were subsequently broken down into the following four types of construction on a regional basis:

1) Residential
2) Non-Residential
3) Road Engineering
4) Non-Road Engineering (Sewers, Watermains, etc.)

Residential and non-residential building demand was determined on the basis of the values of building permits for each of these two types of construction. To forecast the short-term demand for aggregates in the Niagara Region, it was assumed that ratios of building permits in the Region to total building permits in the Central Ontario region in the past will be valid over the forecast period. Non-road engineering construction was assumed to be directly related to total building construction and allocations of demand in a sub-region like Niagara were made on the basis of total building permits in the Central Ontario region.

The projected demand for aggregates for road building purposes was forecast on the basis of individual contracts for road building within each of the counties or regional municipalities, capital budget forecasts for provincial and municipal road building etc. The total demand forecast in each economic region was distributed to regional municipalities, counties and districts using constant factors between regional municipalities and regions (except for road building).

This model was developed for short term forecasts (4 years) and was based on past trends in construction activity on a regional level. Two scenarios were chosen. In the first scenario, it was assumed that the construction activity by type in Ontario regions during the years 1978 to 1981 would be approximately the same as the average proportion in the Province during the 1971-1978 period. In the second scenario, it was assumed that construction activity by type in Ontario regions during the 1978-1981 period would follow the Ontario trend of the 1971-1978 period. This 'extrapolation' is good on a short term basis for a region such as the Central Ontario region.

2.2.2 Model Used by the Regional Municipality of Niagara (Regional Niagara, 1981)

The forecasting model used by the Regional Municipality of Niagara (Regional Niagara, 1981) distributed the demand into the the same four categories that the Ministry of Natural Resources model used, ie:

1) Residential Construction
2) Non-Residential Construction
3) Road Engineering
3) Non-Road Engineering

Residential and non-residential building construction expenditures were forecast on the basis of the value of building construction permits issued in the Niagara Region. For residential construction, the study assumed a growth rate of plus 1 to 2 percent between 1981 and 1985, and an average of plus 2 to 3 percent between 1985 and 1996. For non-residential construction, a growth rate of 1% in real terms was forecast during 1981 and reaching 2.2 percent by 1986. By 1996, the growth rate for non-residential construction was expected to average 3.2 percent over the remainder of the forecast period. More recent studies of projected trends in building construction have shown that, housing starts decreased as the recession deepened through to 1982 but the assumptions given in the study of projected growth rates are probably still quite valid in the long term.

Road construction expenditures on municipal roads over the years 1971 through 1979 quoted in the 1981 study by the Regional Municipality of Niagara (Regional Niagara, 1981) were found to be comparable to those determined by our study of municipal spending over the years following (ie. 1980 through 1983), as determined from MTC data (see Table 2.4). Provincial spending (as quoted by MTC officials), on the other hand was much less in the years following 1979.

Due to a lack of data on so-called non-road engineering construction in the Niagara Region, aggregate consumption in this category was based on forecasts of expenditures on water and sewer construction. It was found that water and sewer construction represented approximately 20 percent of the total expenditures on non-road engineering and would continue to be so over the forecast period.

All of the construction expenditures in each of the four categories were multiplied by input factors which were based on Ministry of Natural Resources studies.

This model is, in many ways, much simpler than that described in section 2.2.1 yet it can be considered to be more valid since it does not suffer from the inherent differences that might occur between the trends within the Central Ontario region and those of the Niagara Region.

2.3 Forecasting Methodology Used for the Niagara Region

2.3.1 Introduction

Since the availability of concrete sand will likely be a major consideration within the Niagara Region if production from the Fonthill kame was phased out, it was decided to choose a model which could be used to forecast the demand for concrete aggregates separately. Such a model was used in the Ministry of Natural Resources' 'Mineral Aggregate Transportation Study' which was carried out by Peat Marwick and Associates (Elek, 1980).

This model was used to forecast the demand for mineral aggregates in the following four categories:

1) Bulk concrete consumption (excluding concrete used in road construction)
2) Residential building construction
3) Road construction
4) Non-residential building construction and non-road engineering construction (sewers, watermains, foundry sand etc.)

Unlike similar models, non-residential and non-road engineering construction were combined into one category with concrete consumption considered separately. Since concrete was treated separately, only those aggregates other than that used in concrete were included in the forecasts for categories 2) and 4). Historical evidence has shown that concrete used in roads does not follow the model developed for concrete consumption.

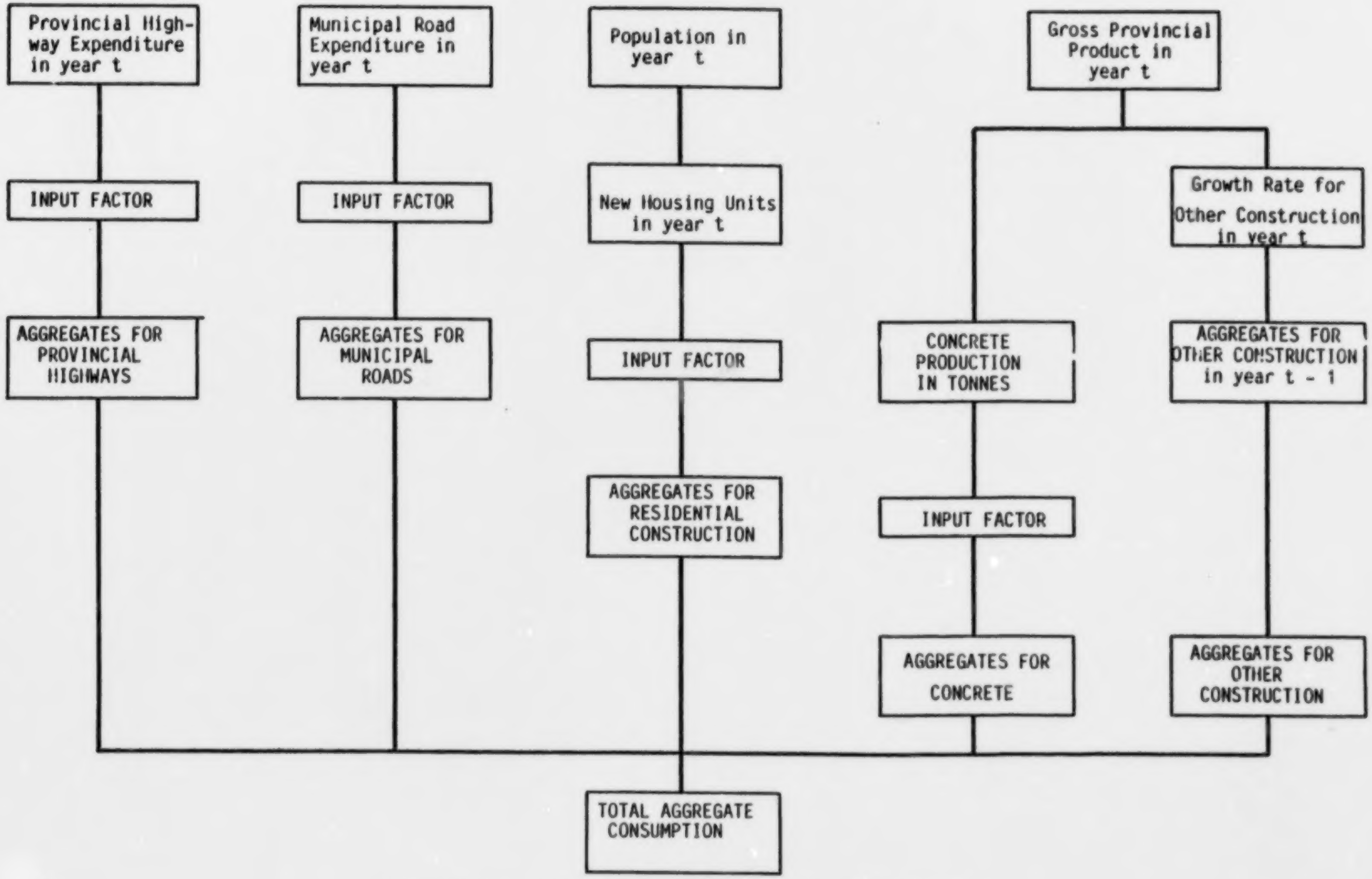
The process used to determine the forecasts of aggregate consumption from the year 1984 to 2000 was structured according to the flowchart shown in Figure 2.1 and involved the following steps:

1) An economic projection for the Gross Provincial Product was prepared.

2) The bulk consumption of concrete (in tonnes) in Ontario was determined for the forecast period using a formula dependent on the gross provincial product. A suitable factor (1.05 tonnes of aggregates per tonne of concrete, including wastage) was then used to determine the consumption of concrete aggregates (excluding that used in roads) in the Niagara Region.

3) Forecasts were prepared for the numbers of housing starts projected for the Region by determining population by age group over the forecast period and employing factors representing the propensity of that age group to form households. A suitable input factor (150 tonnes of aggregate consumption per housing unit, excluding concrete) was then employed to determine aggregate consumption for residential use (excluding concrete).

4) Road construction expenditures for both provincial and municipal roads (including subdivision roads) were determined for the forecast period and suitable input factors in tonnes/dollar were employed to forecast aggregate demand.


Provincial High-way Expenditure in year t
INPUT FACTOR
AGGREGATES FOR PROVINCIAL HIGHWAYS
Municipal Road Expenditure in year t
INPUT FACTOR
AGGREGATES FOR MUNICIPAL ROADS
Population in year t
New Housing Units in year t
INPUT FACTOR
AGGREGATES FOR RESIDENTIAL CONSTRUCTION
Gross Provincial Product in year t
CONCRETE PRODUCTION IN TONNES
INPUT FACTOR
AGGREGATES FOR CONCRETE
Growth Rate for Other Construction in year t
AGGREGATES FOR OTHER CONSTRUCTION in year t - 1
AGGREGATES FOR OTHER CONSTRUCTION
TOTAL AGGREGATE CONSUMPTION

FORECASTING METHODOLOGY FOR AGGREGATE CONSUMPTION IN YEAR t

Figure 2.1

5) The value of 'Other Construction' in Ontario which includes non-residential and non-road engineering construction was determined using a formula based on the projected gross provincial product. The growth rates determined from this formula were applied to the residual aggregate consumption (ie. total consumption - (concrete consumption + road construction consumption + residential construction consumption) for a base year to determine aggregate consumption projected for this category.

Details of the above process are given in the remaining sections of this Chapter.

2.3.2 Gross Provincial Product Forecast

Discussions with members of the Conference Board of Canada, Statistics Canada and the Ministry of Treasury and Economics for Ontario indicate that the most optomistic growth rate of the Gross Provincial Product in real terms from the end of 1984 until the end of the century would be approximately 3 per cent. The GPP over the forecast period in constant $1971 at a growth rate of 3 per cent is presented in Table 2.1.

2.3.3 Bulk Consumption of Concrete

A forecasting model for the bulk consumption of concrete has been developed in the Ministry of Natural Resources' Mineral Aggregate Transportation Study (Elek, 1980). In that study, it was found that the production of concrete depends on two major factors:

- the Gross Provincial Product in the year of interest
- the change in the Gross Provincial Product over the four years preceding the year of interest

Through linear regression of historical data over a 17 year period, it was found that the bulk consumption of concrete for the Province of Ontario in terms of the Gross Provincial Product can be best represented by:

$$C_t = 0.3 P_t + 1.1 (P_t - P_{t-4})$$

where:

C_t = Concrete Consumption in year t, in thousands of tonnes, excluding concrete used in road construction

P_{t-4} = Gross Provincial Product in the year 4 years before t, in millions of constant 1971 dollars

FORECASTS OF CONCRETE DEMAND AND VALUE OF 'OTHER CONSTRUCTION' IN ONTARIO

Year	Gross Provincial Product (Constant $1971) 000,000's (1)	Demand for Concrete (tonnes) 000,000's* (2)	Value of Other Construction (Constant $1971) 000,000's** (3)	Growth Rate of (3) % (4)
1980	50,500			
1981	52,700			
1982	49,800			
1983	51,600		1440	-18.0
1984	54,300	20.5	1670	+15.7
1985	55,900	20.3	1730	+ 4.0
1986	57,600	25.9***	2150	+23.9
1987	59,400	26.3	2160	+ 0.6
1988	61,100	25.8	2100	- 2.4
1989	63,000	26.6	2150	+ 2.0
1990	64,900	27.4	2190	+ 2.0
1991	66,800	28.2	2240	+ 2.0
1992	68,800	29.1	2280	+ 2.1
1993	70.900	30.0	2330	+ 2.1
1994	73,000	30.9	2380	+ 2.1
1995	75,200	31.8	2430	+ 2.1
1996	77,400	32.7	2480	+ 2.1
1997	79,800	33.7	2540	+ 2.1
1998	82,200	34.7	2590	+ 2.2
1999	84,600	35.8	2650	+ 2.2
2000	87,200	36.8	2700	+ 2.2

* Determined Using: $C_t = 0.3 P_t + 1.1 (P_t - P_{t-4})$

where: C_t = The concrete consumption in year t, in thousands of tonnes excluding roads

P_t = The gross provincial product in year t

** Determined Using: $B_t + E_t = 700 + 0.016P_t + 0.085 (P_{t-1} - P_{t-4})$

where: B_t = The value of non-residential building in millions of constant $1971 in year t

E_t = The value of selected non-road engineering construction in Ontario in millions of constant $1971 in year t

*** Substantial increase between 1985 and 1986 due to the rather large change in gross provincial product between 1982 and 1985.

Table 2.1

This equation was used to forecast the consumption of concrete in Ontario over the years 1984 to 2000 using the projections of the gross provincial product. These results are shown in Table 2.1.

Studies of the historical use of aggregates in Ontario shows that the ratio of the consumption of aggregates in Niagara to that of Ontario's consumption has decreased over the years 1976 to 1981 and levelled off at approximately 3.3%. For the purposes of this study, it has been assumed that the consumption of concrete in the Region is also 3.3% of the total consumption in Ontario and will remain so over the forecast period. Using an input factor of 1.05 tonnes of aggregate per tonne of concrete (to account for losses in the manufacturing of cement and concrete) (Elek, 1980), the quantities of concrete aggregate consumed (excluding that used on roads) over the years 1984 to 2000 were determined and the results are shown in column (1) of Table 2.2. Since the bulk consumption of concrete includes all concrete products, it was determined through a concrete production / aggregate consumption study that, fine aggregates represent 45 percent by weight (weighted average of fine aggregate versus coarse aggregate useage by all major ready mix, concrete brick, block and pipe manufacturers) of all concrete aggregates used in the Region. Therefore, the concrete fine aggregate requirements (excluding concrete used in roads) for the Region are shown in Column (2) of Table 2.2.

2.3.4 Residential Construction

The determination of the quantity of aggregates which will be required for residential construction is dependent upon the number of new housing units which will be needed over the forecast period.

This was determined in the following manner:

1) Optomistic population projections for the Niagara Region to 2001 were obtained from publications of the Ontario Government (Ontario Statistics 1982).

2) Using projections of the composition of the population to the year 2001 prepared for the Ontario Ministry of Housing (Peter Barnard Associates, 1977), the population breakdowns for the Region were determined to the year 2001. The population in each age group was then multiplied by factors representing the propensity of that age group to form households which were also determined from the Ontario Ministry of Housing projections. This resulted in a prediction of the number of households within Niagara for the forecast period, the results of which are shown in Figure 2.2

3) In order to calculate housing starts, the following three determinations were made:

    a) The change in the number of households each year.
    b) The total number of households at the end of each year multiplied by the replacement rate which was determined as .0019 housing units/total housing stock (Elek, 1980).

FORECAST FOR
CONCRETE CONSUMPTION
(Excluding Concrete Used in Road Construction)

Year	(1) Total Concrete Aggregates Required (tonnes) 000's	(2) Total Annual Demand for Fine Concrete Aggregates* (tonnes) 000's	(3) Total Cumulative Demand for Fine Concrete Aggregates (tonnes) 000's
1984	710	320	320
1985	704	317	640
1986	897 **	404	1,040
1987	911	410	1,450
1988	894	402	1,850
1989	922	415	2,270
1990	949	427	2,700
1991	977	440	3,140
1992	1,010	454	3,590
1993	1,040	468	4,060
1994	1,070	482	4,540
1995	1,100	496	5,040
1996	1,130	510	5,550
1997	1,170	525	6,070
1998	1,202	541	6,611
1999	1,240	558	7,170
2000	1,280	574	7,740

* Assume 45 % of (1)

** Increase reflected in substantial change in concrete demand between 1985 and 1986 (See *** Table 2.1)

Table 2.2

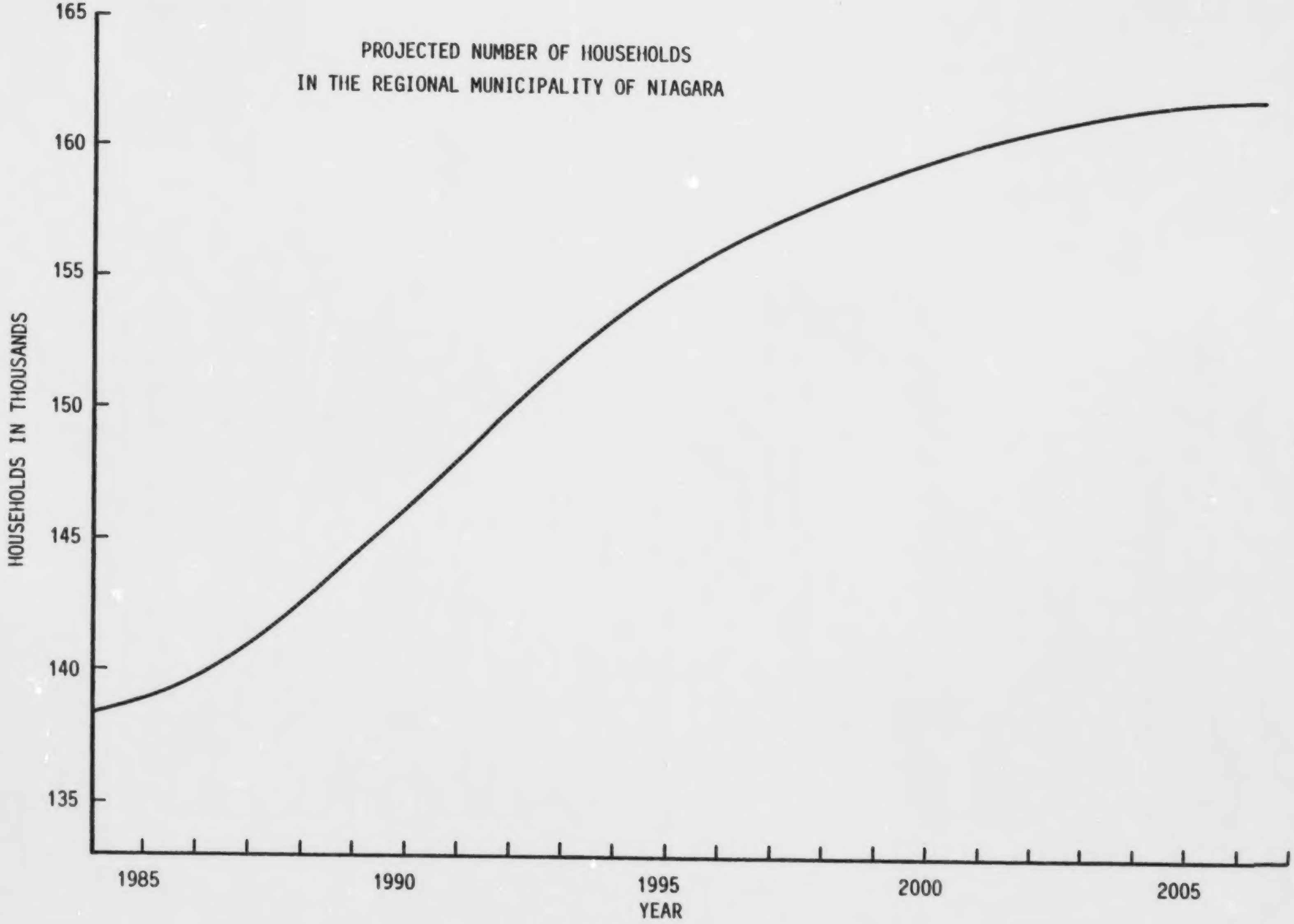

PROJECTED NUMBER OF HOUSEHOLDS
IN THE REGIONAL MUNICIPALITY OF NIAGARA
HOUSEHOLDS IN THOUSANDS
165
160
155
150
145
140
135
1985
1990
1995
2000
2005
YEAR

Figure 2.2

c) The determination of a) + b) multiplied by the required vacancy rate which was optimistically assumed at 3 per cent (Elek, 1980).

4) The values determined in 3(a), 3(b) and 3(c) were added together and multiplied by 150 tonnes of aggregates per housing unit (excluding concrete aggregates) (Elek, 1980). The results are shown in Table 2.3.

2.3.5 Road Engineering

Road engineering construction consumes the largest proportion of aggregates of any single category and therefore is very important in the overall aggregate consumption forecast within the Region.

As in other models, the aggregates consumed by road engineering in the Region were based on forecasts for annual construction expenditures on both municipal and provincial roads.

Historical municipal expenditures on road construction were determined by adding up total road expenditures for all municipalities within the Region (from information provided by the Ministry of Transportation and Communications (MTC)) between 1980 and 1983 and then converting them to constant $1971 by using the tender price index supplied by MTC. These expenditures along with those determined by the Region (Regional Niagara, 1981) for the years 1971 to 1979 are shown in Table 2.4. Based on information obtained from MTC personnel, the municipal expenditures were plotted and then extrapolated to the year 2000 (see Figure 2.3).

The amount of mineral aggregates used for Municipal road construction per 1000 constant 1971 dollars was assumed to be 128.1 tonnes (Regional Niagara, 1981). This value was multiplied by the forecasted municipal construction expenditures and the results are shown in Table 2.5.

Historical provincial road construction expenditures for the Region over the years 1980 to 1983 with a preliminary estimate for 1984 were supplied by the Ministry of Transportation and Communications. Discussions with representatives there indicated that there will likely be one or two major road resurfacing jobs done per year in the Region. In addition, work on Highway 406 will continue over the forecast period and a major new section to the highway will probably begin within 3 to 4 years. It is also likely that work will begin on the widening of the QEW in both directions during the 1990's which will significantly increase the aggregate requirements in the Region. Work on such a highway would continue over the remainder of the forecast period at an approximate rate of one interchange per year.

Studies by Elek (1980) of historical data from numerous contracts for provincial highways indicated that there is a substantial but irregular variation in the input factors from year to year. Their study indicated that an average input factor of 105.8 tonnes per 1000 constant 1971 dollars would be a reasonable assumption. The projected provincial expenditures on roads were multiplied by this input factor and these results together with the totals for both provincial and municipal roads are also included in Table 2.5.

RESIDENTIAL CONSTRUCTION
PROJECTIONS OF AGGREGATE USAGE
(Excluding Concrete)

Year	(1) Households 000's	(2) Housing Units Required	(3) Aggregate Required (Tonnes)* 000's
1984	138	850	128
1985	139	787	118
1986	140	1,100	165
1987	141	1,620	242
1988	143	1,820	274
1989	144	2,240	336
1990	146	2,140	321
1991	148	2,140	322
1992	150	2,460	369
1993	152	2,150	323
1994	154	1,950	292
1995	155	1,750	262
1996	156	1,540	231
1997	157	1,340	201
1998	158	1,290	193
1999	159	1,187	178
2000	160	1,054	158

* Assumed 150 tonnes / housing unit (excluding concrete aggregates)

Table 2.3

ROAD CONSTRUCTION EXPENDITURES

(000,000's of Constant 1971 Dollars)

Year	Municipal Expenditures (From Regional Niagara, 1981)	Provincial Expenditures (From Regional Niagara, 1981)
1971	22.4	26.9
1972	21.0	21.9
1973	25.3	29.8
1974	21.2	25.9
1975	23.2	24.3
1976	21.0	20.7
1977	21.3	19.7
1978	20.1	17.1
1979	20.5	17.3
	(Information From MTC Personnel)	(Estimated by MTC Personnel)
1980	17.4	5.3
1981	16.2	7.8
1982	17.0	7.0
1983	15.0	7.2
1984	15.2	5.2*

* Estimate based on other information obtained from MTC personnel

Table 2.4

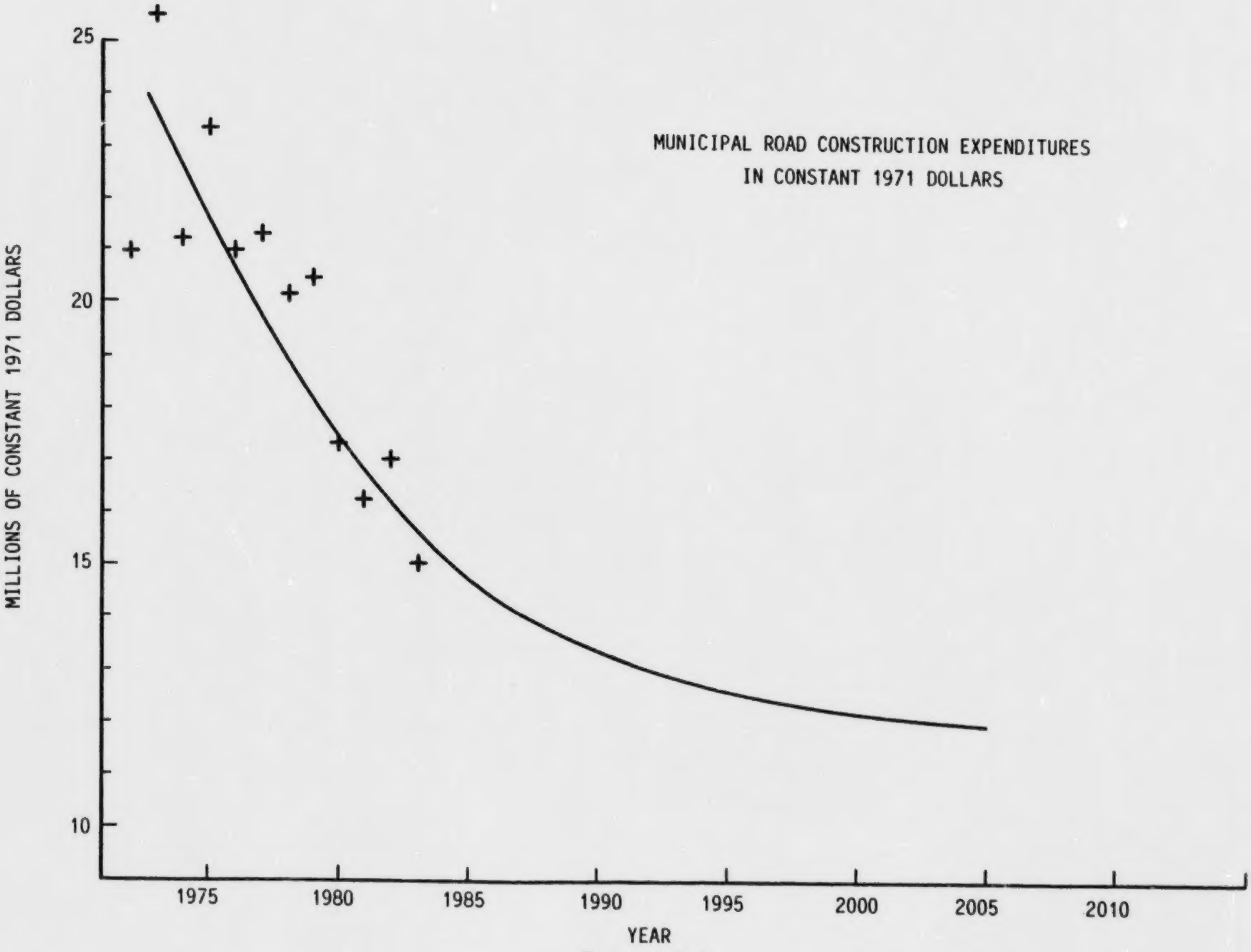

MUNICIPAL ROAD CONSTRUCTION EXPENDITURES
IN CONSTANT 1971 DOLLARS
MILLIONS OF CONSTANT 1971 DOLLARS
25
20
15
10
1975
1980
1985
1990
1995
2000
2005
2010
YEAR

Figure 2.3

ROAD CONSTRUCTION

PROJECTIONS OF AGGREGATE USAGE

Year	MUNICIPAL CONSTRUCTION		PROVINCIAL CONSTRUCTION		TOTAL TONNAGE REQUIRED FOR ROAD CONSTRUCTION (5) (Tonnes) 000's	TOTAL CONCRETE REQUIRED*** (6) (Tonnes) 000's	TOTAL CONCRETE AGGREGATE REQUIRED**** (7) (Tonnes) 000's	TOTAL FINE CONCRETE AGGREGATE REQUIRED***** (8) (Tonnes) 000's
	(1) Municipal Expenditures (Constant $1971) 000,000's	(2) Aggregates Required* (Tonnes) 000's	(3) Provincial Expenditures (Constant $1971) 000,000's	(4) Aggregates Required** (Tonnes) 000's				
1984	15.2	1,950	5.20	553	2,370	61	64	29
1985	14.7	1,880	2.49	263	2,150	52	54	24
1986	14.4	1,840	2.49	263	2,100	51	53	24
1987	14.1	1,804	1.76	186	1,990	48	50	23
1988	13.8	1,770	2.49	263	2,030	49	51	23
1989	13.6	1,740	1.76	186	1,930	46	48	22
1990	13.4	1,720	2.49	263	1,980	48	50	23
1991	13.2	1,690	1.83	194	1,890	45	47	21
1992	13.0	1,670	2.57	272	1,940	47	49	22
1993	12.9	1,650	3.03	321	1,970	48	50	23
1994	12.7	1,630	3.03	321	1,950	47	50	22
1995	12.6	1,610	3.03	321	1,940	47	49	22
1996	12.5	1,600	3.03	321	1,920	47	49	22
1997	12.4	1,590	3.03	321	1,910	46	49	22
1998	12.3	1,580	3.03	321	1,900	46	48	22
1999	12.2	1,570	3.03	321	1,890	46	48	22
2000	12.1	1,550	3.03	321	1,880	46	48	22

* Input factor assumed to be 128.1 tonnes / 1000 constant 1971 dollars

** Input factor assumed to be 105.8 tonnes / 1000 constant 1971 dollars

*** Assume 3 tonnes of concrete / 1000 constant 1971 dollars

**** Assume 1.05 tonnes of aggregate are required per tonne of concrete

***** Assume fine aggregates are 45 % by weight of total concrete aggregates

Table 2.5

The total concrete Aggregates required for road construction are shown in Column (7) of Table 2.5 assuming that approximately 3 tonnes of concrete are required per $1,000 ($ 1971) and 1.05 tonnes of aggregate are required per tonne of concrete. If it is further assumed that fine aggregates represent approximately 45 percent by weight of total concrete aggregates, then the total fine concrete aggregate requirements for road construction are shown in column (8) of Table 2.5.

2.3.6 Non-Residential and Non-Road Engineering Construction

After the forecasts for concrete, residential and road construction aggregate consumption were completed, forecasts had to be prepared for the remaining aggregate-consuming categories which include:

- Non-Residential building construction - schools, hospitals, office buildings etc.
- Non-Road engineering construction - sewers, waterworks etc.

A forecasting model was developed in the Mineral Aggregate Transportation Study (Elek, 1980) which was done for the Ministry of Natural Resources to model the non-residential and non-road portion of the aggregate consuming activities in the Province of Ontario. This formula is given by:

$$(B_t + E_t) = 700 + 0.016\, P_t + 0.085\, (P_{t-1} - P_{t-4})$$

where:

B_t is the value of non-residential building construction in Ontario in millions of constant (1971) dollars

E_t is the value of selected non-road engineering construction in Ontario in millions of constant (1971) dollars in the year t

P_t is the Gross Provincial Product of Ontario in millions of constant (1971) dollars in year t

P_{t-1} , P_{t-4} is the same as above, one and four years before the year above respectively

This formula was used to calculate the value of non-residential building and non-road engineering construction in Ontario over the time of interest using the forecast for the Gross Provincial Product. The growth rate over the forecast period as determined by the changes in the value of non-residential and non-road engineering construction was calculated and the results are given in Table 2.1.

A base year of 1983 was chosen and the total aggregates consumed for that year was assumed to be equal to the net production in the Region (production + imports - exports). The tonnages of aggregates calculated for residential building construction, concrete consumption and road construction were subtracted from the total aggregates consumed for 1983. The residual amount was assumed to represent non-residential, non-road and other aggregate-consuming activities.

It was then assumed that the growth rate in the consumption of aggregates for this last category would be the same as that determined for Ontario. The residual amount calculated for 1983 was then factored by the growth rate calculated for Ontario and the future growth in the quantities of aggregate consumed in the Niagara Region were determined. These results along with the totals forecast for each year are included in Table 2.6.

All of the results obtained in this demand forecast are presented in Tables 2.7 and 2.8. Table 2.7 shows the total annual and cumulative consumption of aggregates in the Region from the beginning of 1984 to the year 2000. The annual demand is likely to remain fairly constant increasing slightly from 3.4 to 3.7 million tonnes over the remainder of the century. A cumulative demand of approximately 60.5 million tonnes would be required from the end of 1983 to the end of the year 2000.

In addition, column (2) of Table 2.2 and column (8) of Table 2.5 have been combined in column (2) of Table 2.8 to show the total annual demand for concrete fine aggregates in the Region. The demand for concrete fine aggregates (of which concrete sand is one component) will increase from about 349,000 tonnes in 1984 to 596,000 tonnes by the end of the year 2000. This will represent a total cumulative demand for concrete fine aggregates of 8.1 million tonnes (column (3), Table 2.8).

It should be noted that the latest figures indicate that concrete sand production from Fonthill was about 214,000 tonnes in 1984. The concrete fine aggregate consumption noted above was calculated to be about 349,000 tonnes in 1984 but this, of coarse, does not include either dredged sand from the Niagara Bar being sold as concrete sand or the 70,000+ tonnes (estimated) of concrete fine aggregates from quarries presently being used in concrete products (see Table 8.1). Despite the recent decline in concrete fine aggregate demand, it is felt that demand projections for 1984 are within about 12 percent of actual. However, the long term projections given above may be overstated (conservative - high demand estimate) and are only to be used for illustrative purposes.

2.3.7 Comparison with Study by the Regional Municipality of Niagara (Regional Niagara, 1981)

The projections of cumulative aggregate consumption within the Region as determined by the Region (Regional Niagara, 1981) and this Study are shown in Figure 2.4.

Although the categories into which the consumption was broken down into were very different, the cumulative consumption of aggregates determined in the Region's study were remarkably comparable to this Study. It might be argued that this is due to the similarities involved in the projection of road engineering which maintains a rather substantial proportion of the total aggregate consumption of the Region.

OTHER CONSTRUCTION
PROJECTIONS OF AGGREGATE USAGE

Year	Other Construction (Tonnes) 000's
1984	234
1985	244
1986	302
1987	304
1988	296
1989	302
1990	308
1991	315
1992	321
1993	328
1994	335
1995	342
1996	349
1997	357
1998	364
1999	372
2000	381

Table 2.6

TOTAL CONSUMPTION OF ALL AGGREGATES IN
THE REGIONAL MUNICIPALITY OF NIAGARA

Consumption in Thousands (000's) of Tonnes

Year	Concrete (Excluding Concrete Aggregates used in Road Construction)	Residential Construction	Road Construction	Other Construction	Total Demand	Cumulative Demand
1984	710	128	2,370	234	3,440	3,440
1985	704	118	2,150	244	3,220	6,660
1986	897	165	2,100	302	3,460	10,120
1987	911	242	1,990	304	3,450	13,570
1988	894	274	2,030	296	3,490	17,060
1989	922	336	1,930	302	3,490	20,550
1990	949	321	1,980	308	3,560	24,110
1991	977	322	1,890	315	3,500	27,610
1992	1,010	369	1,940	321	3,640	31,250
1993	1,040	323	1,970	328	3,660	34,910
1994	1,070	292	1,950	335	3,650	38,560
1995	1,100	262	1,940	342	3,640	42,200
1996	1,130	231	1,920	349	3,630	45,830
1997	1,170	201	1,910	357	3,640	49,470
1998	1,200	193	1,900	364	3,660	53,130
1999	1,240	178	1,890	372	3,680	56,810
2000	1,280	158	1,880	381	3,700	60,510

Table 2.7

TOTAL CONSUMPTION OF CONCRETE FINE AGGREGATES* IN THE NIAGARA REGION

YEAR	ANNUAL DEMAND FOR CONCRETE FINE AGGREGATE * REQUIRED** (Tonnes) 000's	CUMULATIVE DEMAND FOR CONCRETE FINE AGGREGATE* REQUIRED (Tonnes) 000's
1984	349	349
1985	341	690
1986	428	1,120
1987	433	1,550
1988	425	1,980
1989	437	2,420
1990	450	2,870
1991	461	3,330
1992	476	3,810
1993	491	4,300
1994	504	4,800
1995	518	5,320
1996	532	5,850
1997	547	6,400
1998	563	6,960
1999	580	7,540
2000	596	8,140

Note: *Concrete fine aggregates includes all agregates used as the fine component for all concrete products. This includes both concrete sand and quarry screenings.

**Column (2) of Table 2.2 is added to Column (8) of table 2.5.

Table 2.8

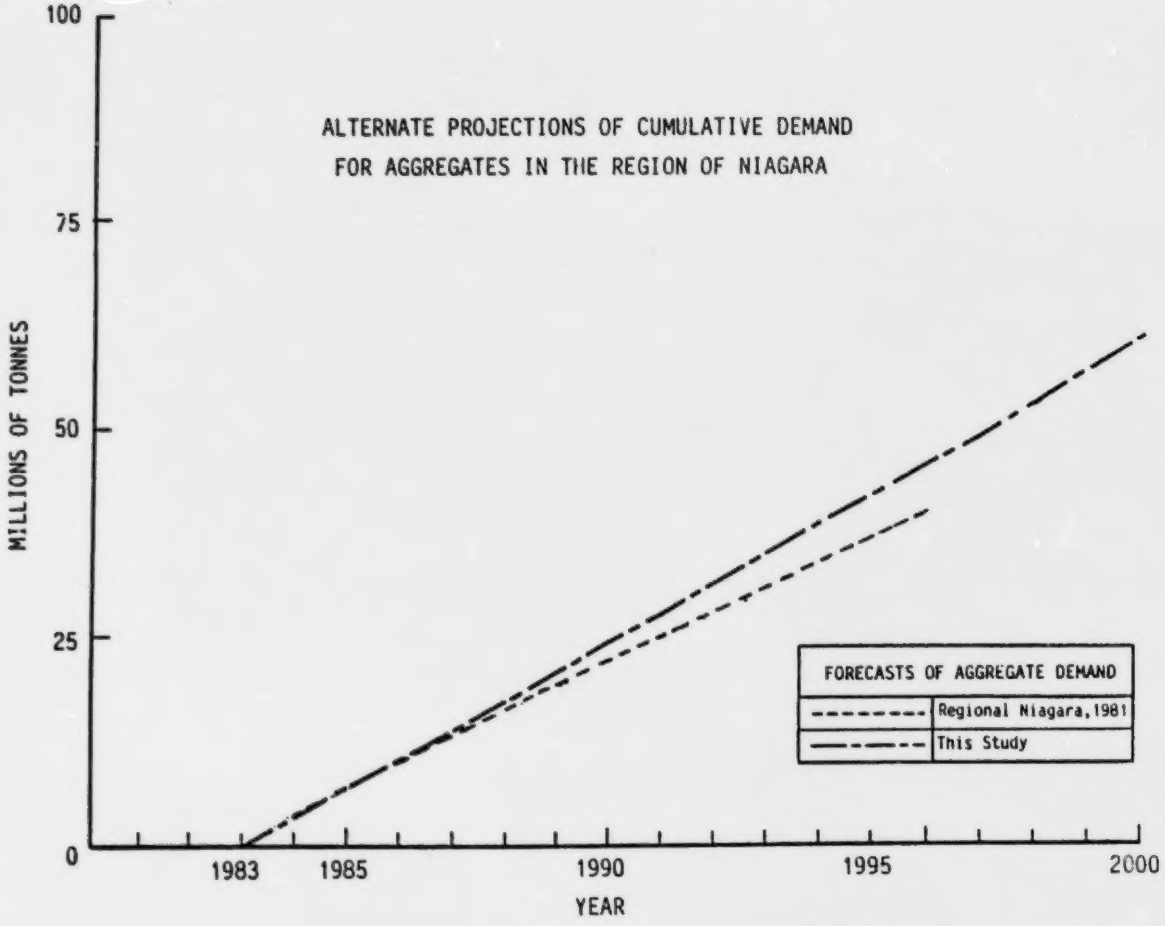

ALTERNATE PROJECTIONS OF CUMULATIVE DEMAND
FOR AGGREGATES IN THE REGION OF NIAGARA
MILLIONS OF TONNES
100
75
50
25
0
1983
1985
1990
1995
2000
YEAR
FORECASTS OF AGGREGATE DEMAND
Regional Niagara,1981
This Study

Figure 2.4

3.0 DREDGED MATERIAL

3.1 Location and Formation of the Niagara Bar

The Niagara Bar is a composite large deposit of granular material covering approximately 33.75 km2 at the mouth of the Niagara River (see Figure 3.1 (a)). It straddles the Canada-U.S. border extending 4.5 km to the north of the river mouth and 7.5 km east-west along the shore.

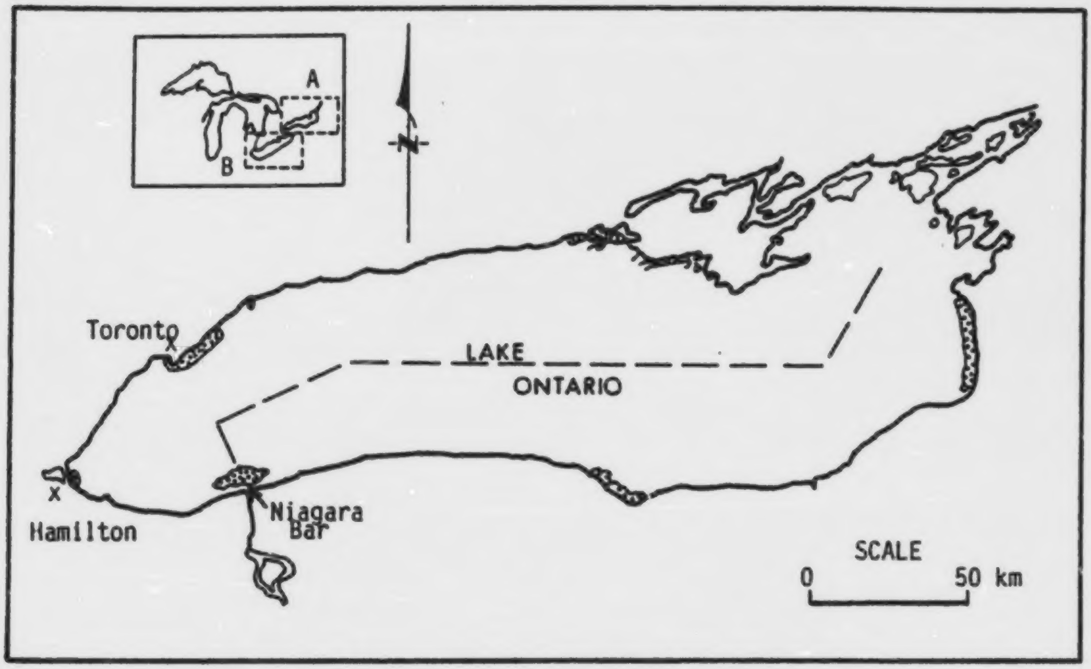
The Niagara Bar is made up of two partially overlapping subaqueous bars. The outer bar is found at water depths between 15 and 30 m, while the inner one is found at depths ranging from 2.5 to 12 m (see Figure 3.2 from Sly, 1983a and the Canadian Hydrographic Services, 1984). The Bar is a composite feature developed at different times in the past (Sly, 1983).

The older portion of the Bar (Outer Bar) probably formed during times when glaciers had retreated from the lower Great Lake Basins but still dammed the north shores of the upper Great Lakes. The northern and western outlets of the upper lakes were closed and much of the outflow occurred through the Niagara and the southeastern Rome and St. Lawrence River outlets of the Lake Ontario Basin (Hough, 1958; Lewis, 1969). During a low lake stage of the Ontario Basin (Sly and Prior, 1984), considerable erosion occurred within the Niagara Gorge. During this time, parts of the old interstadial and stadial sediments, similar to those found at the St. David Gorge, were reworked forming the outer Niagara Bar. It is likely that only a portion of the original Bar is preserved. Some of it may have been reworked by waves during the transgression of the lake to its present level.

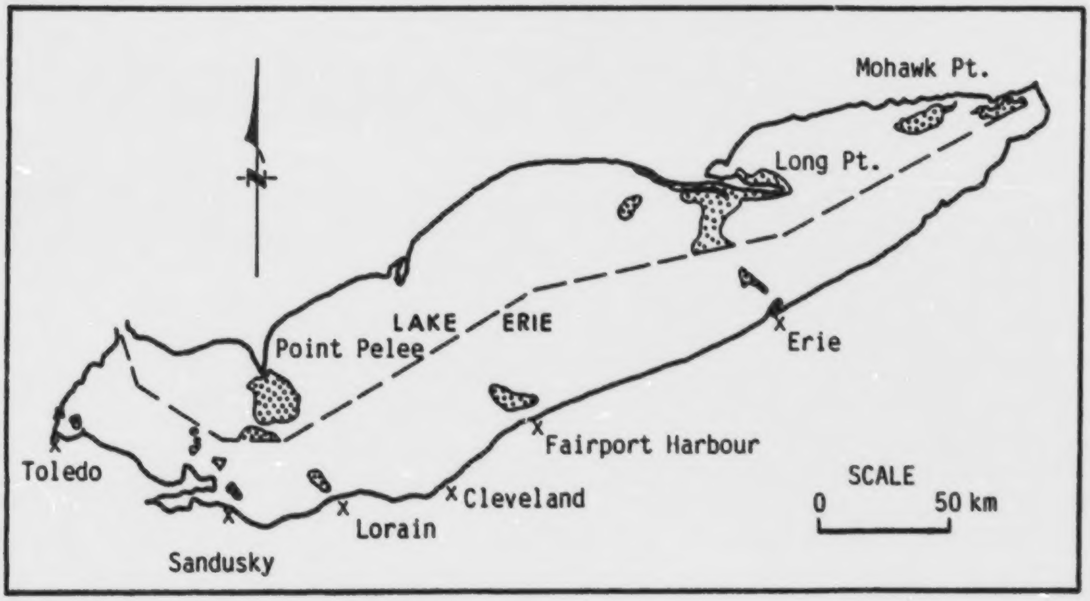
The inner bar overlaps in part and covers the outer bar. This second younger bar may have been formed when the full outflow of the upper lakes was re-routed through Lake Erie and the Niagara Gorge about 4,000 to 5,000 years BP (before present) (Sly, 1983a; Sly and Prior, 1984).

The Niagara Bar is partly composed of materials transported by the river to its mouth and partly derived from shore eroded materials moved eastward by longshore drift. The analyses of the sediments cored by the Canada Center for Inland Waters indicates that an approximate average net rate of sedimentation of 1 mm per year has occurred. Such a rate has been estimated by observing the horizon of Ambrosia (weedgrass) pollen at an average depth of 15.8 cm (range 3 - 39 cm) (from Rukavina, 1976; 1981a). The spreading of Ambrosia in Southern Ontario occurred approximately 120 years ago after the colonization of the land by Europeans and the subsequent development of agriculture.

Human activities have affected the surficial deposits of the bar in many ways. The deforestation of the land and agricultural practices have increased the rate of erosion particularly along the shores. In addition, the numerous building and other activities along the Niagara Gorge have fostered erosion and injected materials into the river. This material ranges from angular rock fragments to manufactured glass. Other materials injected in the fluvial and longshore system


A
B
N
Toronto
LAKE
ONTARIO
Hamilton
Niagara Bar
SCALE
0
50 km

a) Sandbodies in Lake Ontario


Mohawk Pt.
N
Long Pt.
LAKE
ERIE
Point Pelee
Erie
Fairport Harbour
Toledo
Sandusky
Lorain
Cleveland
SCALE
0
50 km

b) Sandbodies in Lake Erie

Figure 3.1 - Sandbodies in Lake Ontario and Lake Erie (after Martini et. al., 1982; Williams et. al., 1980; Smith, S., Personal Communication)

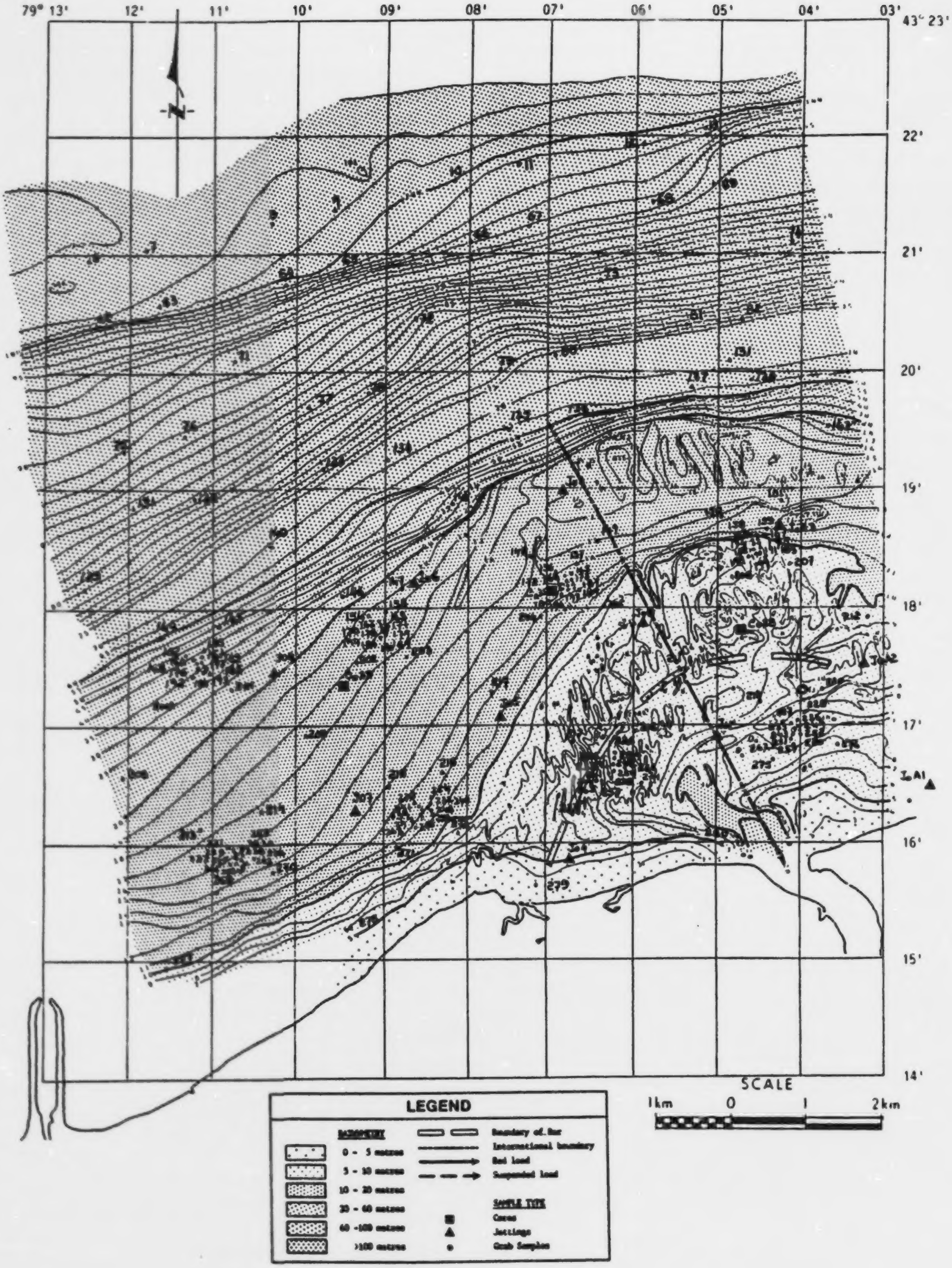

79° 13'
12'
11'
10'
09'
08'
07'
06'
05'
04'
03'
43° 23'
22'
21'
20'
19'
18'
17'
16'
15'
14'
N
SCALE
1km
0
1
2km
LEGEND
BATHYMETRY
0 - 5 metres
5 - 10 metres
10 - 20 metres
20 - 60 metres
60 -100 metres
>100 metres
Boundary of Bar
International boundary
Bed load
Suspended load
SAMPLE TYPE
Cores
Jettings
Grab Samples

Figure 3.2 - Bathemetry Map With Locations of Samples, Jettings and Cores

from possible industrial areas upstream are wood, coal and slag, particularly from the coal-burning ships of the past. All of these materials have found their way into the Niagara Bar and were mixed with the natural sands and silts. This injection of foreign material into the system is continuing today, except that now it consists of solid petroleum products and, more hazardous chemical pollutants (Allen et. al, 1983; Kaminsky et. al., 1983; Thomas, 1983; Sly, 1977, 1983a, 1984).

The processes which have been involved in the formation of the bar and are still active today include:

1) River flow
2) Eastward-moving longshore currents, which also deflect the riverine plume
3) Waves - which are most effective in reworking the bar sediments during storms (see Figure 3.3)

It is not known what direct or indirect effect lake ice has had on developing the characteristics of the bar but it is reported, for instance, that in the shallower parts of Lake Erie, pressure ridges have deeply scoured some of the granular deposits.

The Niagara Bar has gone through a series of stages in the past:

1) Intense rapid development soon after deglaciation followed by:

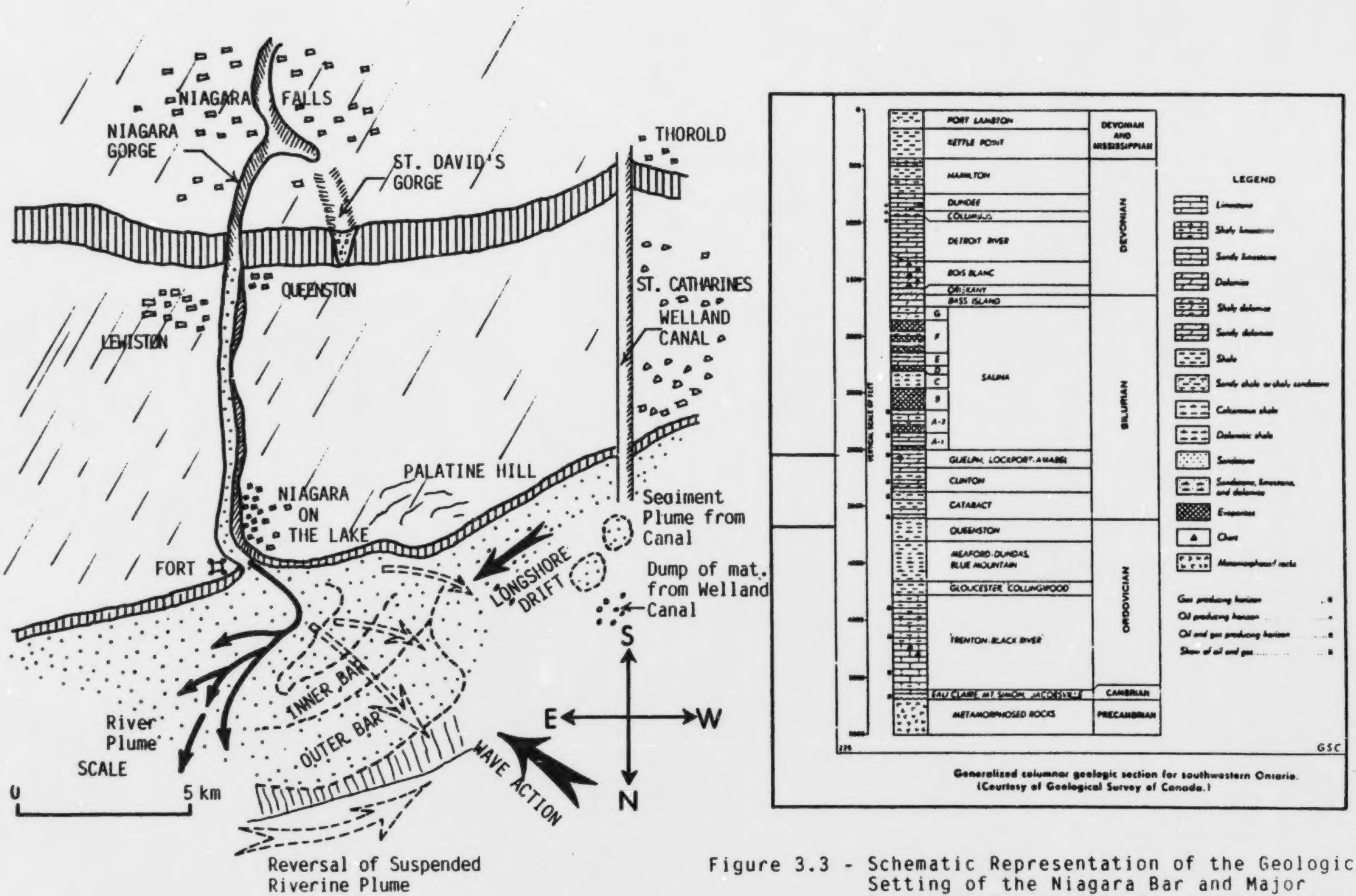
2) Relatively slow growth, except for longshore current transport during the period between 12,000 and 5,000 years ago when the flow of the Upper Great Lakes was to the northeast and northwest and finally:

3) Revitalization after the transgression of the lake level towards the present day Lake Ontario, about 4000 years before present.

The rate of sedimentation as well as changes in the composition of the materials comprising the Bar have been extensively affected by deforestation, agriculture and the technological revolution.

3.2 Material Quality

The grain size distribution along with the presence of undesirable materials, such as chert, manufactured glass, slag, sandstone particles and pebbles, as well as minor light (S.G. less than 2.0) materials such as wood and coal, limits the suitability of part of the deposit for certain aggregate uses. However, previous studies and practical use of dredged materials from Niagara in the past has established that other parts of the Bar (see following sections) contain suitable fine aggregates for both concrete and bituminous paving mixtures (AASHTO, 1974; National Standard of Canada, 1977; Martini et. al., 1983).


NIAGARA FALLS
NIAGARA GORGE
ST. DAVID'S GORGE
THOROLD
QUEENSTON
LEWISTON
ST. CATHARINES
WELLAND CANAL
PALATINE HILL
NIAGARA ON THE LAKE
FORT
Sediment Plume from Canal
Dump of mat. from Welland Canal
LONGSHORE DRIFT
INNER BAR
OUTER BAR
WAVE ACTION
River Plume
SCALE
0
5 km
S
E
W
N
Reversal of Suspended Riverine Plume
PORT LAMBTON
KETTLE POINT
HAMILTON
DUNDEE
COLUMBUS
DETROIT RIVER
BOIS BLANC
ORISKANY
BASS ISLAND
G
F
E
D
C
B
A-2
A-1
SALINA
GUELPH, LOCKPORT-AMABEL
CLINTON
CATARACT
QUEENSTON
MEAFORD-DUNDAS, BLUE MOUNTAIN
GLOUCESTER 'COLLINGWOOD'
'TRENTON-BLACK RIVER'
EAU CLAIRE, MT. SIMON, JACOBSVILLE
METAMORPHOSED ROCKS
DEVONIAN AND MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PRECAMBRIAN
VERTICAL SCALE OF FEET
LEGEND
Limestone
Shaly limestone
Sandy limestone
Dolomite
Shaly dolomite
Sandy dolomite
Shale
Sandy shale or shaly sandstone
Calcareous shale
Dolomitic shale
Sandstone
Sandstone, limestone, and dolomite
Evaporites
Chert
Metamorphosed rocks
Gas producing horizon
Oil producing horizon
Oil and gas producing horizon
Show of oil and gas
GSC

Generalized columnar geologic section for southwestern Ontario.
(Courtesy of Geological Survey of Canada.)

Figure 3.3 - Schematic Representation of the Geological Setting of the Niagara Bar and Major Processes Responsible for its Formation

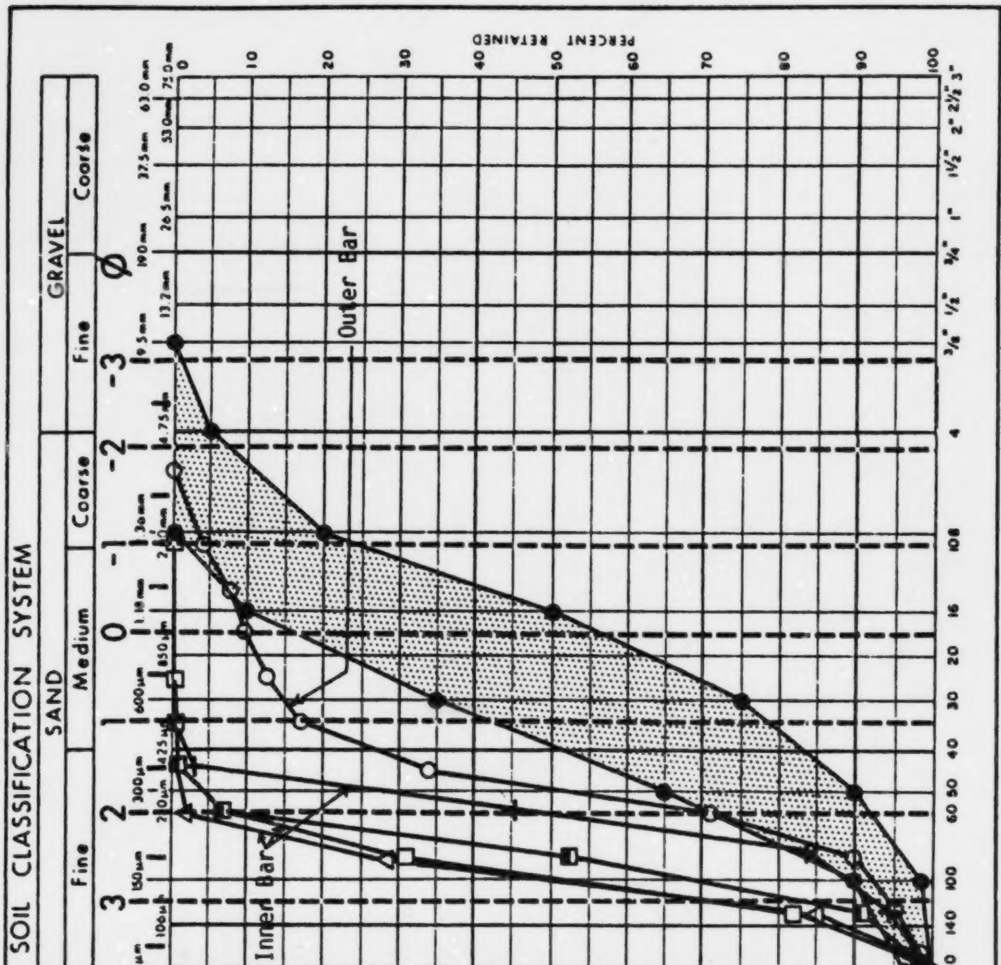
3.2.1 Particle Size Distributions

Grain size information about the Niagara Bar was obtained from approximately 300 surficial samples collected and treated by the Canada Centre for Inland Waters (Sandilands and Sly, 1977), five cores taken to a maximum depth of 1 m (Rukavina, 1981b), 25 samples taken from stockpiles collected and treated by the Hydro-Electric Power Commission and one sample from a Hamilton stockpile recently collected and analyzed by Red-D-Mix Concrete Company (see Appendix III). For this study, ten representative samples have been taken from stockpiles at the Queenston dock (4), Red-D-Mix of Hamilton (1) and, for comparison purposes, from stockpiles at the dock of Erie Sand and Gravel Co. (5) at Erie, Pennsylvania.

The results of the grain size analyses indicate that most of the natural deposits of the bar are not suitable for fine aggregate for concrete (Figure 3.4; Appendix VI). They are suitable, however, for plaster and masonry sand, winter sand and other uses which allow relatively fine-grained material (Figure 3.5). However, samples taken from the stockpile indicate that blended materials can meet the requirements for fine aggregates for concrete (Figure 3.6). Indeed, these dredged sands have been used as standard fine aggregates by the Hydro-Electric Power Commission in the past and they are being used at the present by Red-D-Mix in Hamilton (Figure 3.7). The beneficiation of the fine and very fine natural sands, is obtained, in part, during dredging as the finest particles are rewashed into the lake. Additional benficiation takes place by mixing the fine sand which predominates in the bar with the coarser material found in places where the bar is cut and reworked by the current of the Niagara River. It is common dredging practice to mix approximately one part of coarse sand from near the mouth of the Niagara River, with two parts of finer sands from other parts of the bar (Cptn. J. Leonard, Mckeil Works Boat Ltd., Personal Communication). It can be shown by calculation that mixing such different materials (samples) can produce a blended material which meets the grain size requirements for concrete fine aggregate (Figure 3.8).

The above discussion deals with the availability of sand for fine aggregates. Our research has not found any evidence for availability of any significant amount of coarse aggregate (gravel) suitable for concrete. Therefore, the dredged sand must always be mixed with coarse materials from other sources when used for this purpose.

The few available shallow (40 - 105cm) cores show no great variation with depth, although, some were found to have thin siltier beds or interstrata containing gravel (Figure 3.9). However, if the Niagara Bar behaves as a normal distributary mouth bar, the expectation is that the grain size will decrease with depth, except in those areas which have been crossed by river channels or contain lag deposits which have accumulated at the bottom. Traces of older channels can still be seen on the bar (Figure 3.2); however, it is not known whether the lateral shift of the Niagara channel has occurred regularly, thus forming a basal coarse lag deposit, or whether it has avulsed in response to major floods and storms, thus generating only string-like deposits of coarser material sub-perpendicular to the coast and buried under the bar. It is suspected that the second is the most likely case.

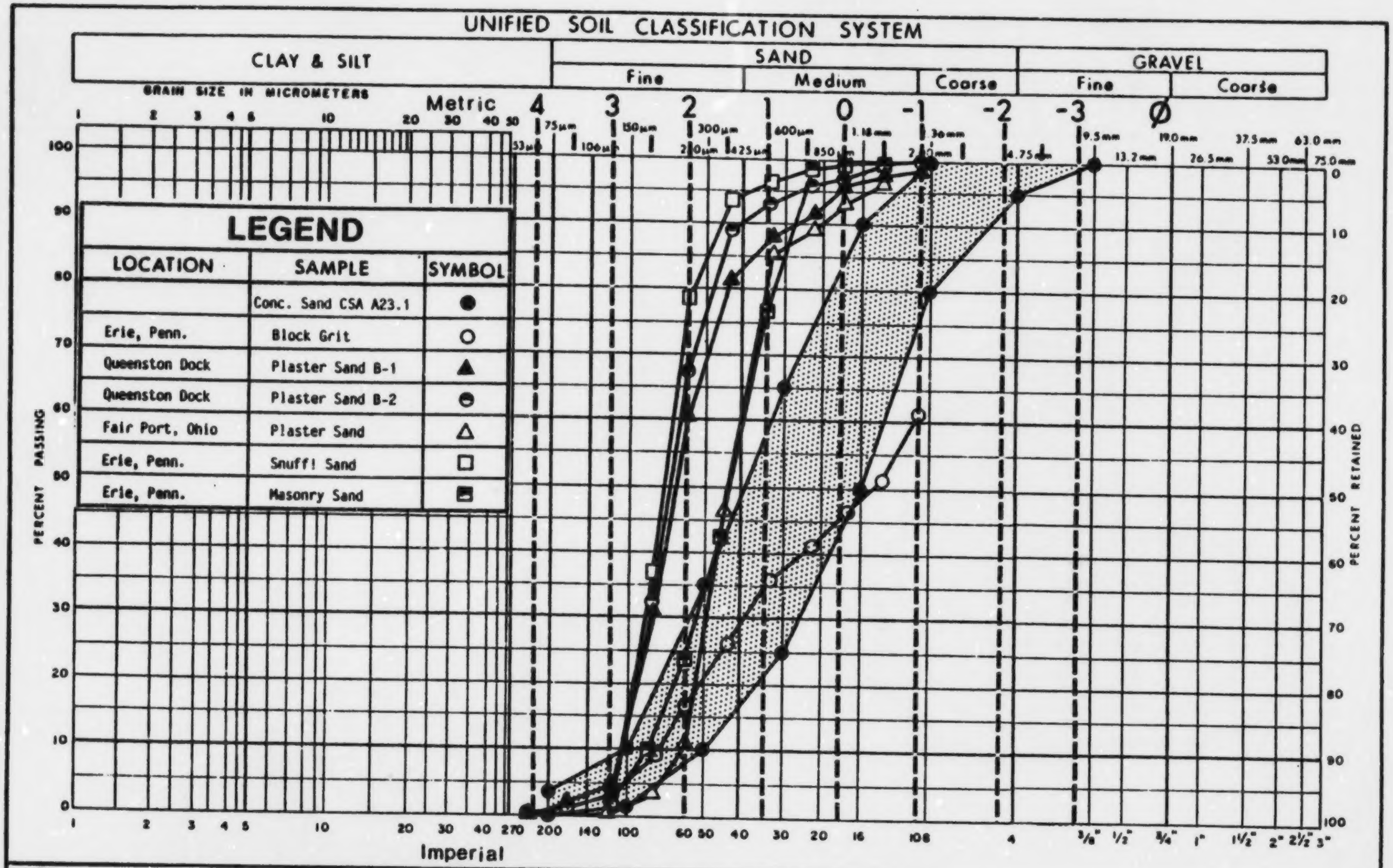


GRAIN SIZE DISTRIBUTION

Northern Portion, Niagara Bar
(Data from Sandilands and Sly, 1977)

FIGURE NO.
3.4

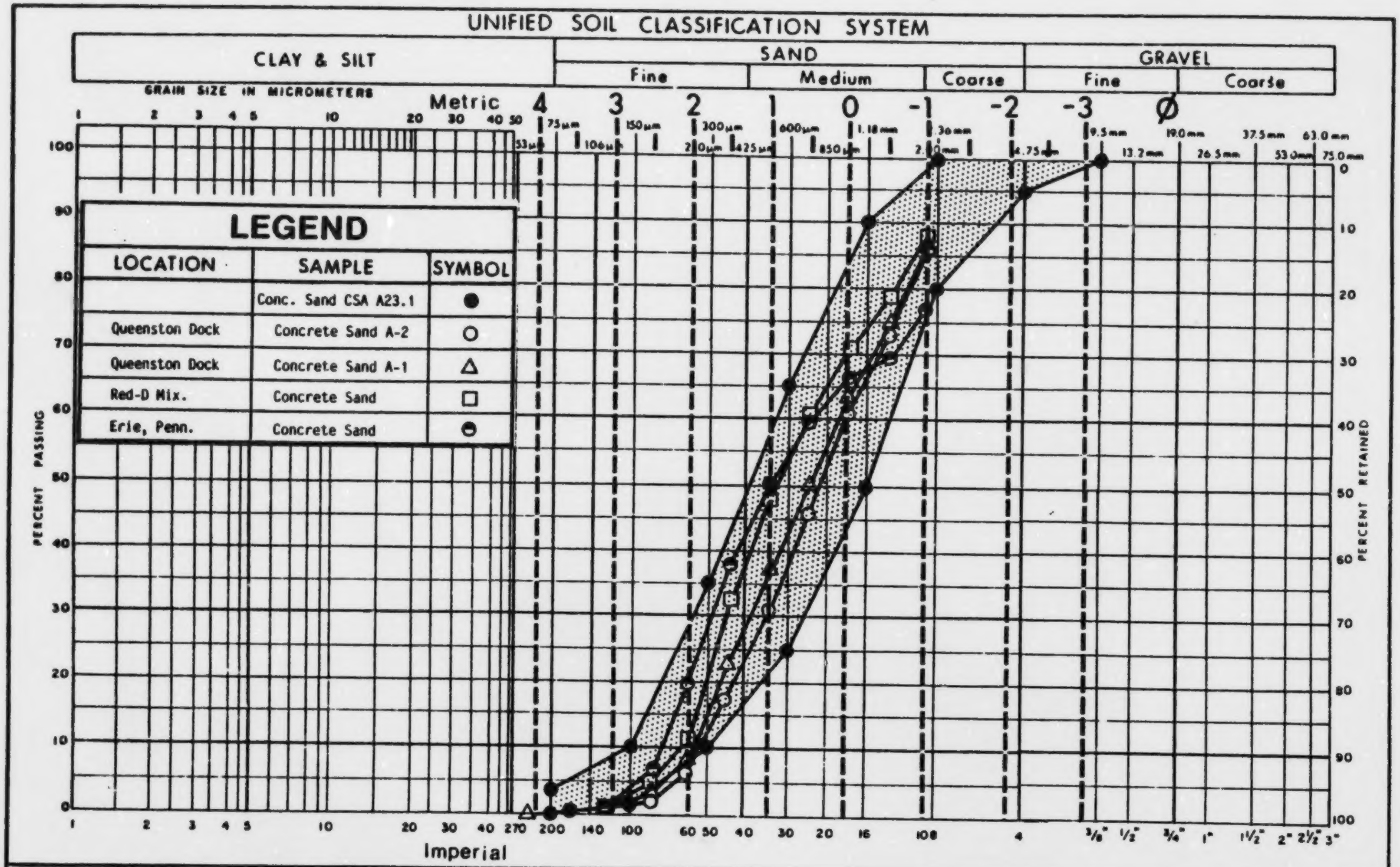
C. MIRZA ENGINEERING INC.
GEOTECHNICAL SPECIALISTS



C. MIRZA ENGINEERING INC.
GEOTECHNICAL SPECIALISTS

GRAIN SIZE DISTRIBUTION
Sands used for Plaster and Masonry Works
(Samples from Stockpiles)

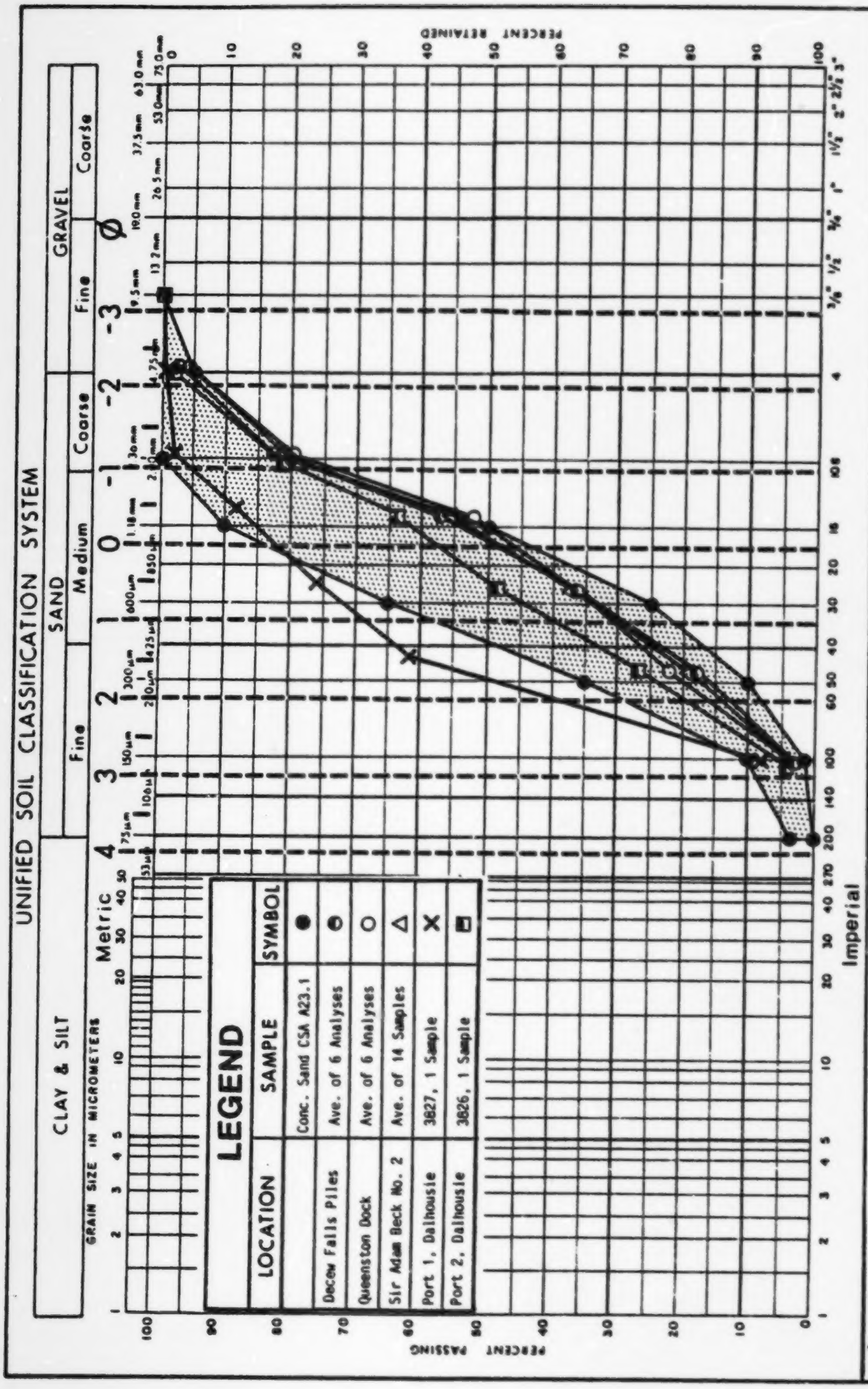
FIGURE NO.
3.5



C. MIRZA ENGINEERING INC.
GEOTECHNICAL SPECIALISTS

GRAIN SIZE DISTRIBUTION
Blended Sands Used as Fine Aggregates for Concrete
(Samples From Stockpiles)

FIGURE NO.
3.6

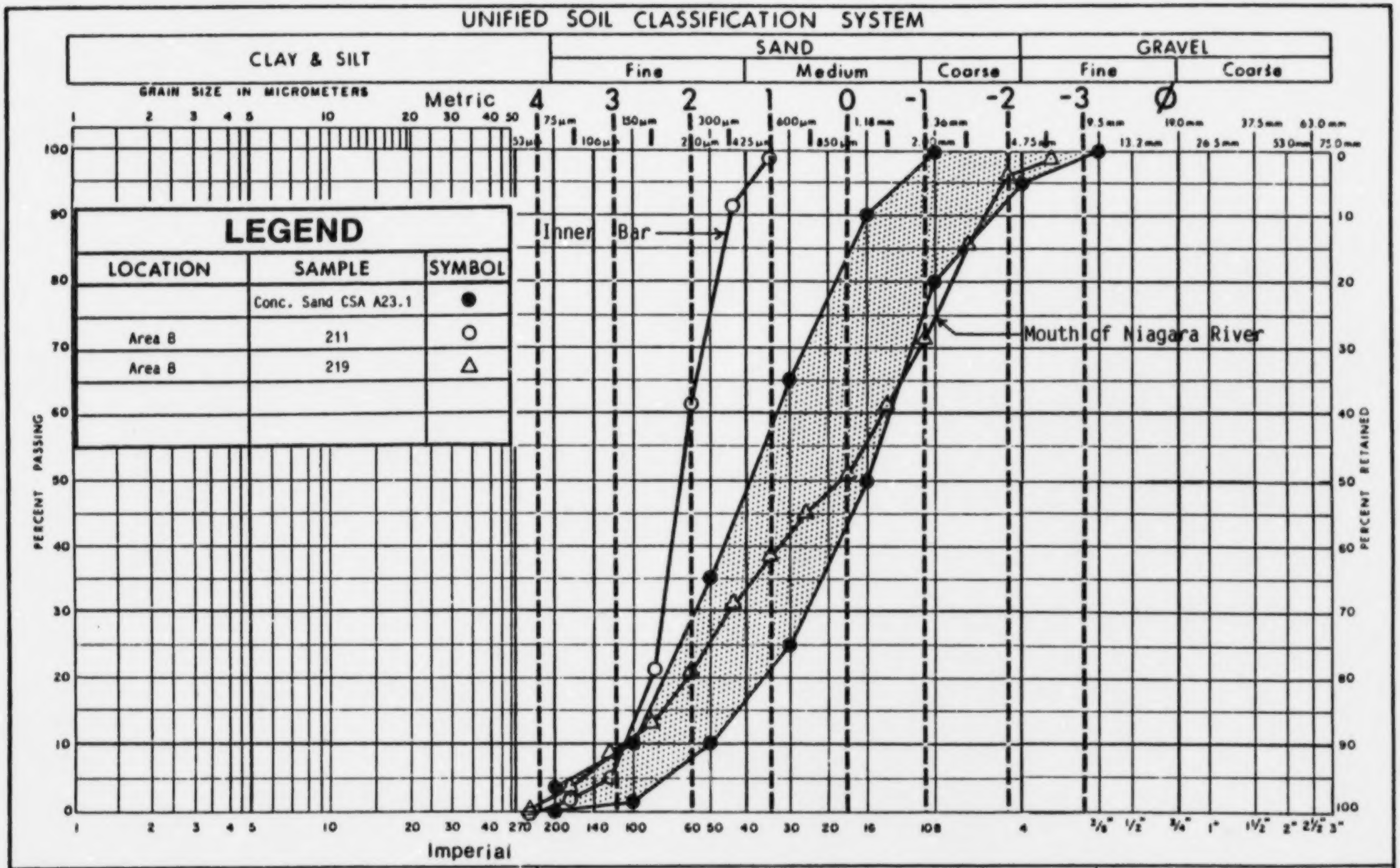


C. MIRZA ENGINEERING INC.
GEOTECHNICAL SPECIALISTS

GRAIN SIZE DISTRIBUTION

Blended Sand From the Niagara Bar
(Used as Fine Concrete Aggregate)

FIGURE NO.
3.7



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GRAIN SIZE DISTRIBUTION

Sands From the River Mouth
Niagara Bar

FIGURE NO

3.8

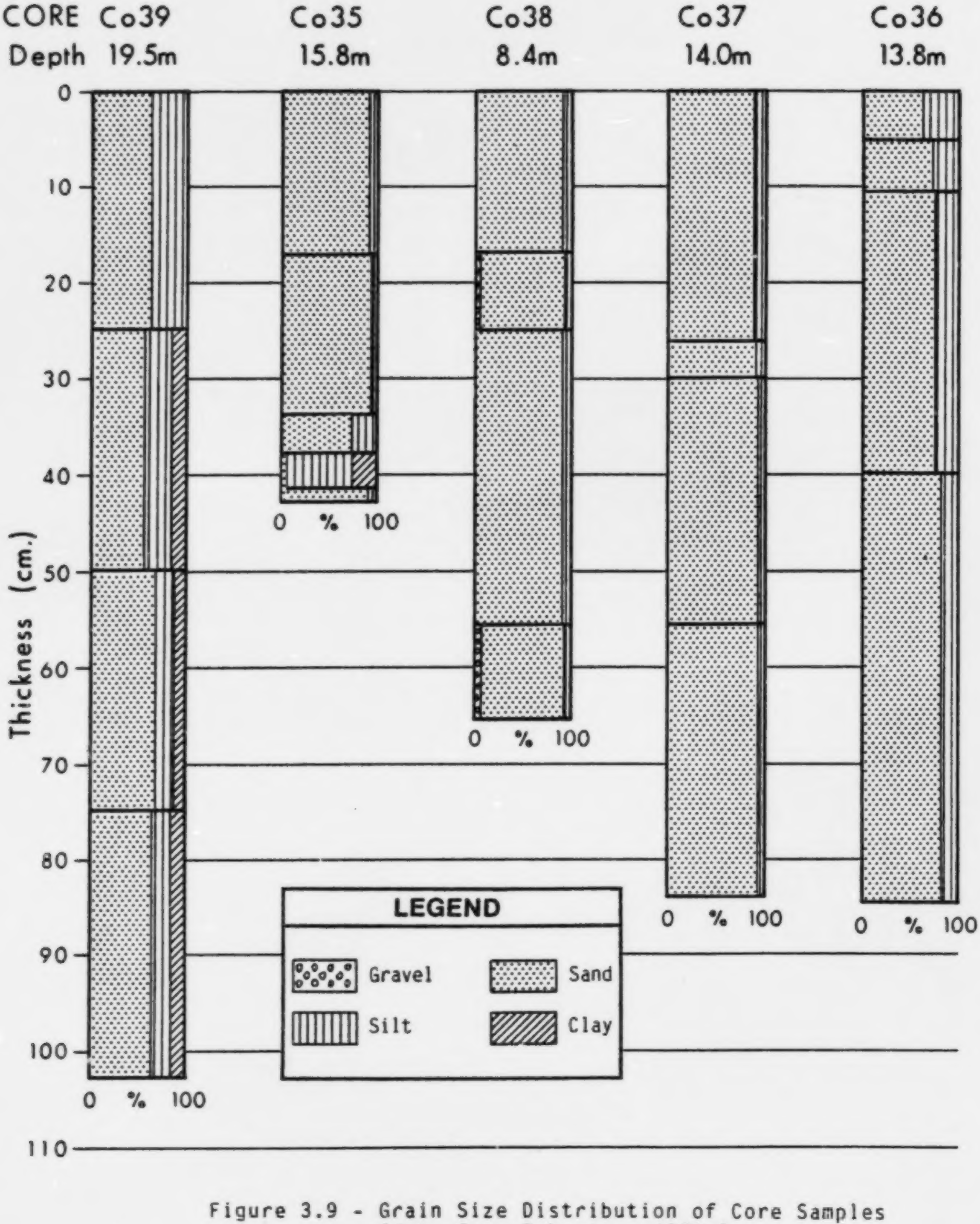
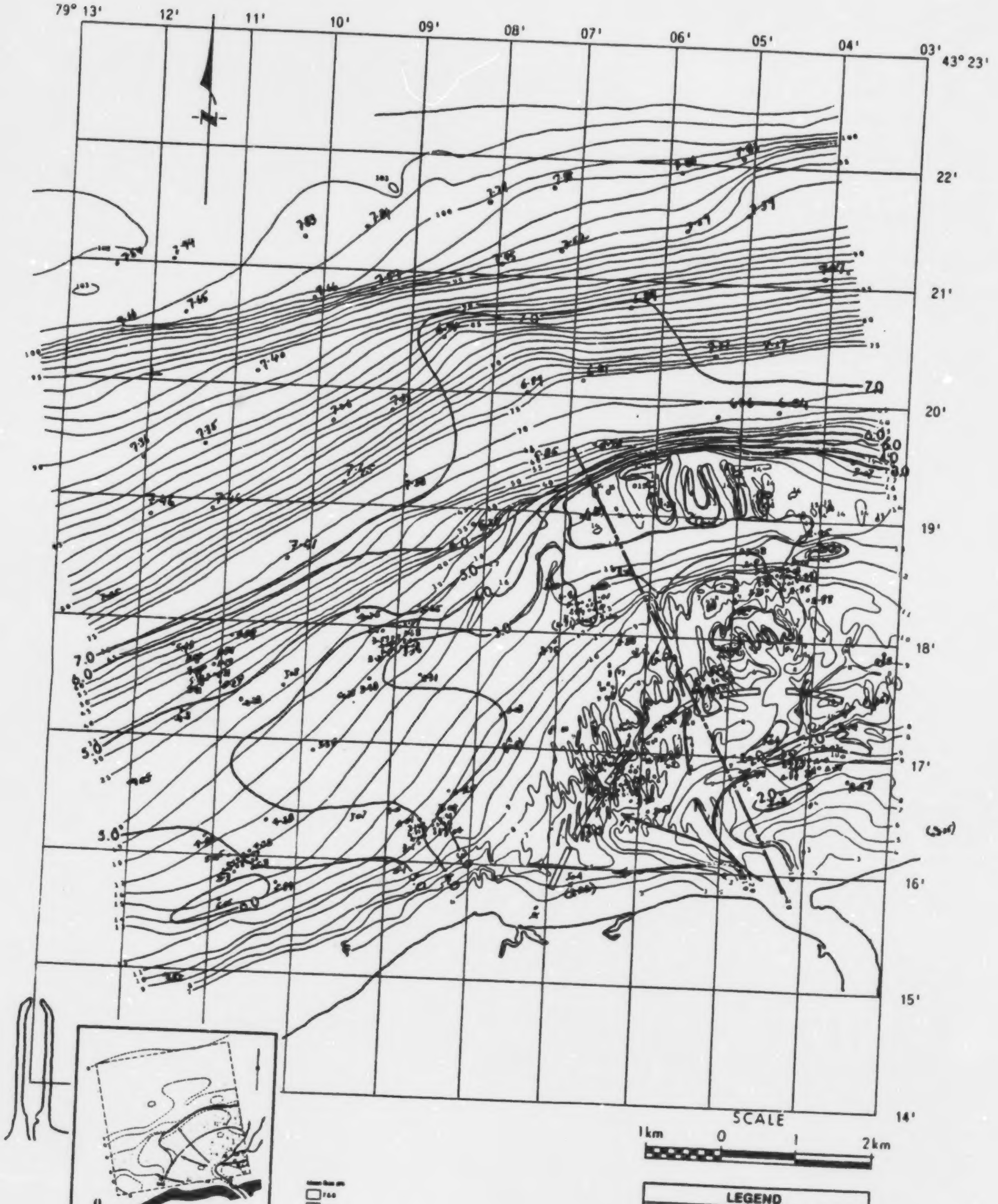


Figure 3.9 - Grain Size Distribution of Core Samples
(data from Rukavina, 1981a)

Two interpretations of the areal distribution of sand on the Niagara Bar are being presented here. The first one was published by Sly in 1983. The second, which has been generated for this report, is based on the same data and is placed on a less generalized bathymetric map obtained from echosounding (Sandilands and Sly, 1977). This second representation is used to clearly demonstrate the underlying assumptions made in constructing the maps from widely scattered data points. That is, that the grain size of the surficial deposits correlates closely with bathymetry (Figures 3.10, 3.11, 3.12, 3.13 and 3.14). For instance, the coarser and more well-sorted sand deposits are found both at the top of the modern bar which is at a water depth of approximately 2.5 to 8 m, and at the top of the ancient outer bar which is at an approximate depth of 15 m (Figure 3.2). The top of the inner bar is being reworked by present day waves. The top of the outer bar may be occasionally reworked during major storms, but its surficial deposit is mostly a relic of the time when the lake level was lower. Another high energy environment which produces coarse, but more poorly-sorted, sand occurs deep within the river channel (Cptn. J. Leonard, Personal Communication).

The river outflow has a significant effect in determining the type of sand deposited in various parts of the Bar. Sly (1983a) states "...The coarsest sediments (mean phi of 1 or coarser) are almost entirely restricted to the major outflow channels of the Niagara River although a small area of coarse material, outside the main channel, may reflect occasional bed load transport a short distance towards the northwest (or this may be a relic deposit)". Essentially, he relates the coarse material to the bedload transported by the Niagara River (Figure 3.11). Considering that at present the Niagara River carries little sediments out from the land, it may be hypothesised that the outflow charges itself with material by eroding part of the southern flank of the Inner Bar and redistributing the sediments and sorting them according to the ensuing energy gradients of the river plume. What therefore becomes very important is to determine whether the coarse sand fraction is an inherent property of the Bar or whether it is naturally renewed by winnowing out of finer materials by the current of the Niagara River.

Sly (1983a) also states that "...most particle size distributions correlate well with bathymetric features and the distribution of Bar sediments is consistent with a joint supply of material from longshore drift in the nearshore zone (west of the river mouth) and from the outflow of the river itself". It is also possible that some ice rafted material is added to the Bar as it is added to parts of the offshore deposits. Although, the morphology of the Bar and the movement of the river plume suggest the influence of this longshore current, the particle sizes of the surficial deposits do not contain clear evidence of this eastward longshore drift. This, together with the yet unexplained correlation of the location of the bar with respect to the small promontory of the Palatine Hill (Niagara-on-the-Lake), suggests that further analysis of the deeper parts of the Niagara Bar is required (Figure 3.2).


79° 13'
12'
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43° 23'
22'
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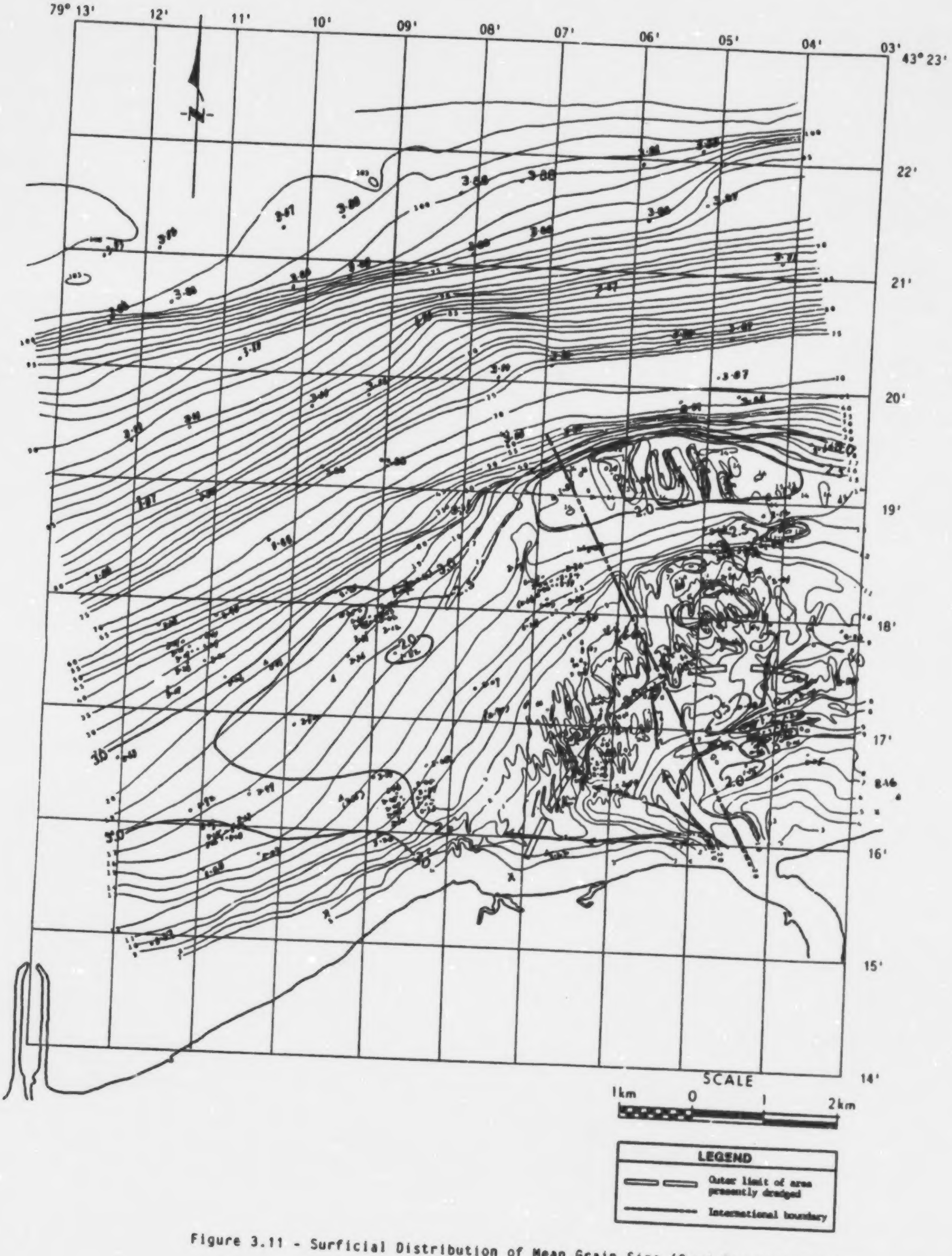
20'
19'
18'
17'
16'
15'
14'
N
7.0
6.0
5.0
4.0
3.0
2.0
SCALE
1km
0
1
2km
LEGEND
Outer limit of area presently dredged
International boundary

Niagara Bar, Lake Ontario: Bathymetry and mean particle size. (From Sly 1983 a)

Figure 3.10 - Surficial Distribution of Mean Grain Size (Whole Sample: Sand, Silt and Clay) (0)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17'
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14'
N
2.0
2.5
3.0
SCALE
1km
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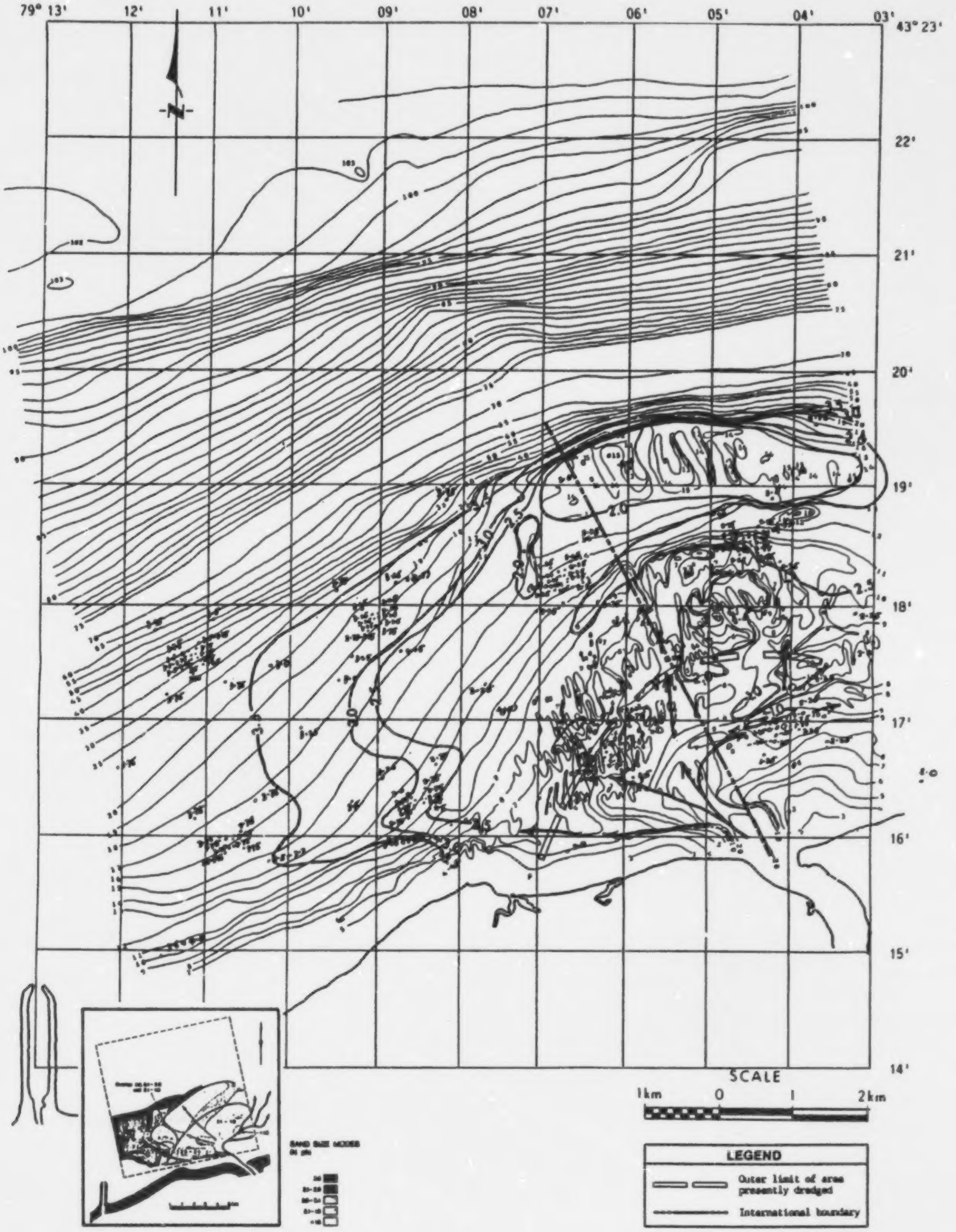
1
2km
LEGEND
Outer limit of area presently dredged
International boundary

Figure 3.11 - Surficial Distribution of Mean Grain Size (Sand Fraction Only) (ø)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18'
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16'
15'
14'
N
2.0
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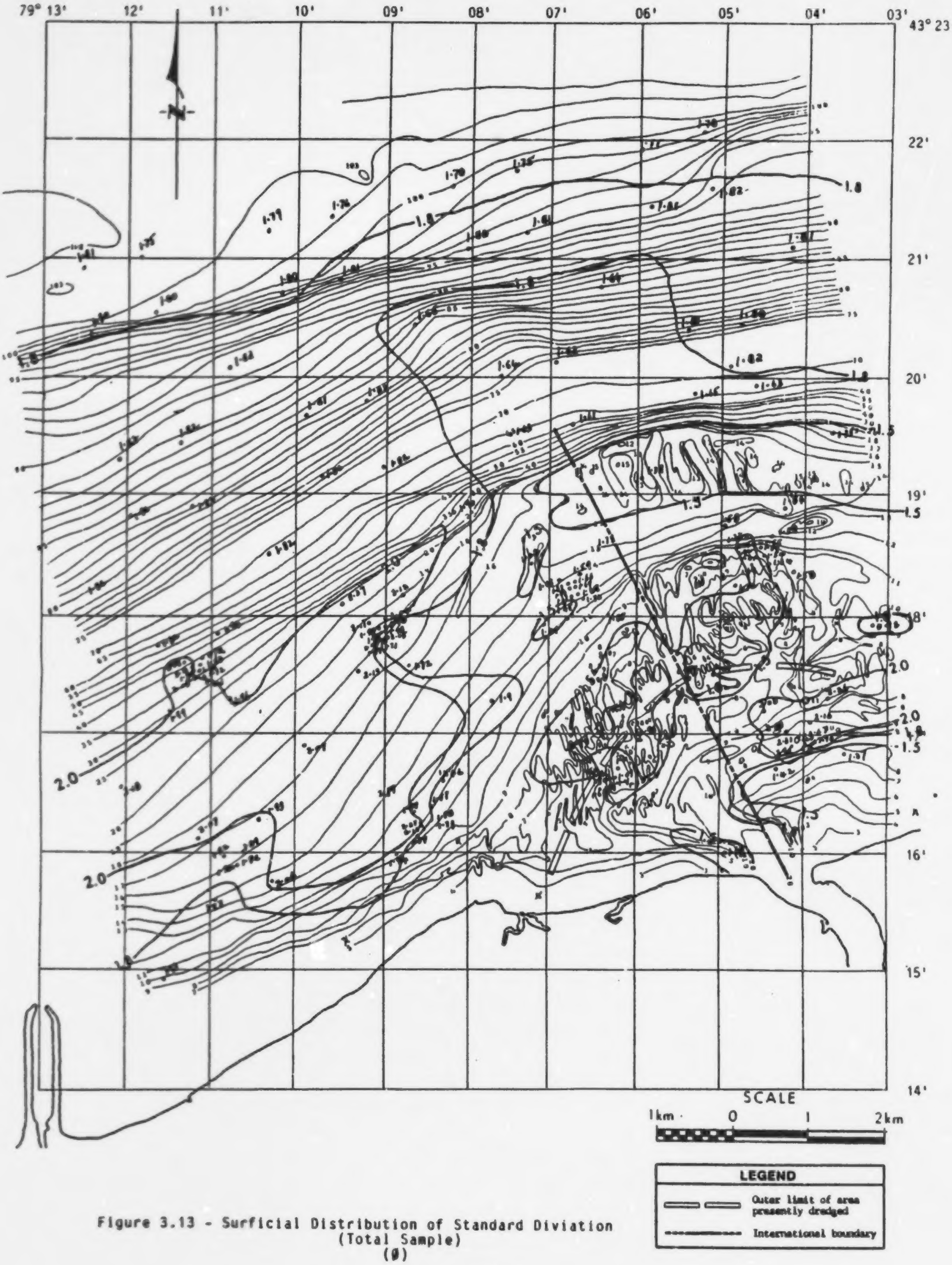
3.0
SCALE
1km
0
1
2km
LEGEND
Outer limit of area presently dredged
International boundary
SAND SIZE MODES

Niagara Bar, Lake Ontario: Sand size modes. (From Sly 1983 a)

Figure 3.12 - Surficial Distribution of Sand Mode
(Sand Fraction Only)
(φ)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43° 23'
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19'
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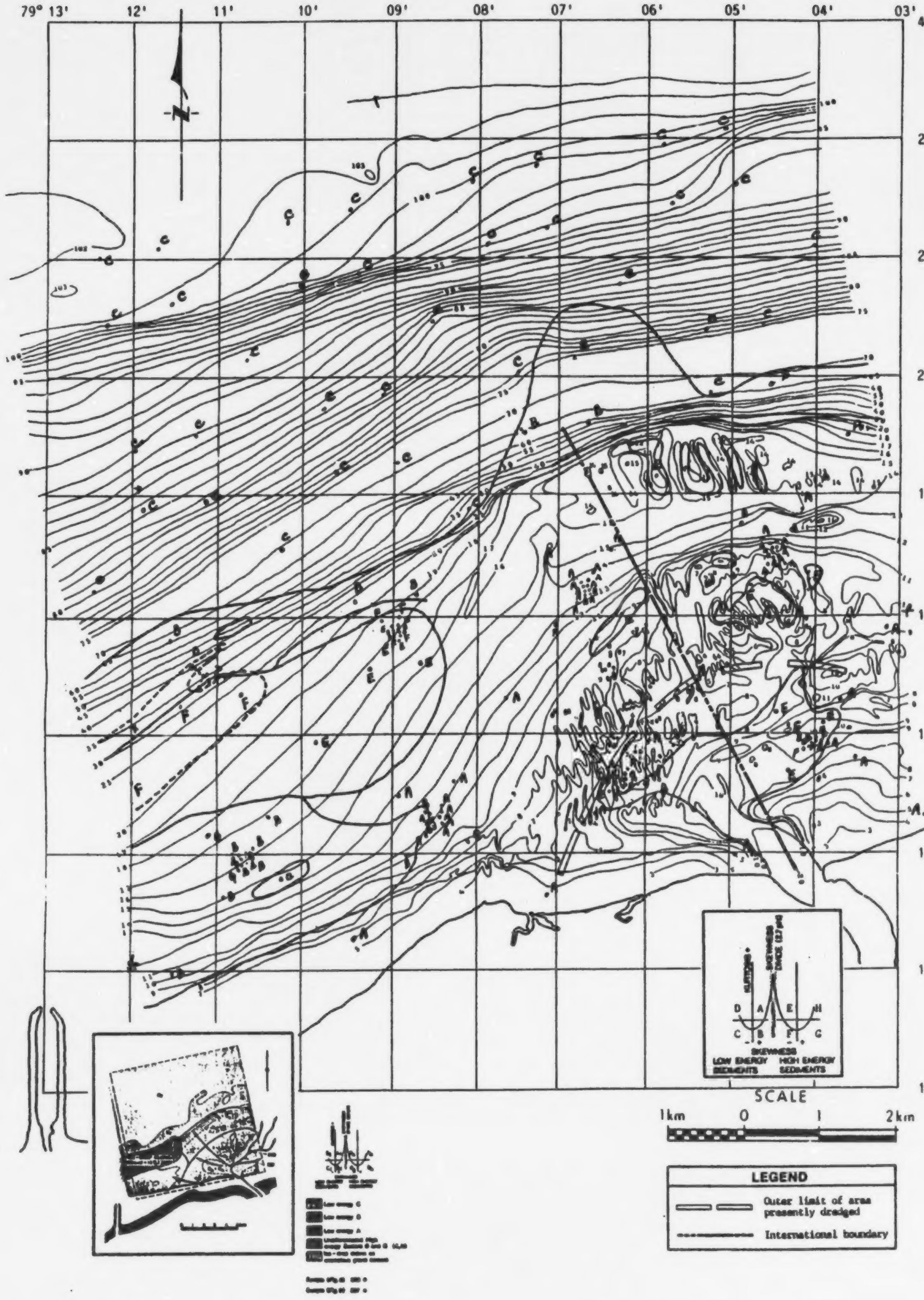
15'
14'
N
1.8
1.5
2.0
SCALE
1km
0
1
2km
LEGEND
Outer limit of area presently dredged
International boundary

Figure 3.13 - Surficial Distribution of Standard Diviation
(Total Sample)
(ø)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N
KURTOSIS +
SKEWNESS
SKEWNESS
INDEX (0.7Φ)
D
A
E
H
C
B
F
G
SKEWNESS
LOW ENERGY SEDIMENTS
HIGH ENERGY SEDIMENTS
SCALE
1km
0
1
2km
LEGEND
Outer limit of area presently dredged
International boundary

Niagara Bar, Lake Ontario: Skewness/kurtosis sectors. (From Sly 1983a)

Figure 3.14 - Surficial Distribution of Skewness / Kurtosis Sectors

3.2.2 Petrographic and Chemical Composition

Detailed petrographic and textural analysis were made on standard fine concrete sand from the Niagara Bar by the research division of the Hydro-Electric Power Commission of Ontario (Appendix IV). Such analyses revealed that chert, one of the potentially deleterious components, was locally abundant (27 percent in gravel size fraction and 9.2 percent in the sand fraction). However, not all varieties of chert are equally reactive, thus not equally deleterious. Essentially, the researchers of the Hydro-Electric Power Commission believe that only the porous slightly-weathered variety is harmful and this type has been found to form about 1.4 percent of the sand fraction and about 3.9 percent of the oversize which did not present a performance problem to them. In addition, it was found that the amount of light material (S.G. less than 2.0) was on the order of 0.5 to 0.8 percent (see Appendix IV).

Petrographic examination of thin sections prepared from dredged sands from the Niagara Bar in this study generally confirms findings by the Hydro-Electric Power Commission (Table 3.1).

The conclusions of the study by the Commission were that the oversize fraction clearly exceeded the 5.0 percent limit (in the Hydro-Electric Power Commission Specification) for deleterious components in aggregates for mass concrete. The sand fraction, which constitutes 95 percent of the dredged material from the Niagara Bar, contained only about 3.3 percent of the undesirable components. In any case, the amount of deleterious materials exceeds the limits (1 percent for chert content) specified for Portland cement and cannot be used without beneficiation for such purpose. These conclusions were confirmed by the laboratory analyses carried out in this Study as well.

Petrographic examination of a dredged sand from Erie, Pennsylvania shows that, with respect to the Niagara Bar, it contains more carbonates in the gravel fraction, yet is free from coal, slag, glass and other man-generated materials. However, it does contain a large amount of silicified (cherty) rock (20.3 percent in gravel fraction, 16.5 percent in sand fraction) which is apparently non-reactive in concrete (S. Smith, Personal Communication; Table 3.1).

Chemical analyses (XRF) of sands taken from the Queenston Dock, Red-D-Mix, at Hamilton and the Erie, Pennsylvania dock do not show major differences except that those from Erie contain a higher concentration of CaO and a lower loss on ignition (LOI). Such differences may be associated with the fact that the Erie sediments may have been derived from a basin richer in limestone whereas those of the Niagara Bar were derived from a basin richer in dolostone. The lower loss on ignition may be associated with a lower amount of shell fragments in Pennsylvania samples. These differences should not greatly affect the relative preference of these sands, although more complete tests would be advisable.

Dredging takes care of a large part of the benefication process with screens used to reject the oversize as well as the fines (silt and clay). The light deleterious materials including the organic matter are floated off. The benefication of the heavier material (such as alkali-reactive chert) can only be achieved by blending the fine aggregates from the Niagara bar with other suitable

PETROGRAPHY OF DREDGED SAND FROM STOCKPILES

	PREVIOUS STUDIES		THIS STUDY					
	Ontario Hydro-electric Power Commission (Niagara Bar)		Bawtinheimer Ltd. (Niagara Bar)		Red-D-Mix (Niagara Bar)		Erie Sand and Gravel (Penn.)	
ROCK FRAGMENTS	Gravel (%)	Sand (%)	Gravel (%)	Sand (%)	Gravel (%)	Sand (%)	Gravel (%)	Sand (%)
Carbonates	24.9	27.0	29.7	20.6	28.4	29.7	49.0	29.7
Sandstones	24.7	20.4	33.3	20.9	30.4	13.2	21.0	7.5
Siltstone	4.2	1.1	0.9	2.4	0.5	3.2	2.8	0.3
Shale	-	0.7	1.8	2.9	1.5	-	-	-
Quartzite	5.3	1.9	8.1	1.2	4.6	-	0.7	-
Granite	3.2	4.7	5.4	0.9	2.6	0.3	2.8	0.3
Meta. Rock	3.2	0.8	0.9	-	2.1	-	2.8	-
Chert*	27.3	9.2	11.7	5.9	13.9	6.8	-	-
Siliceous Shales	-	-	-	-	-	-	20.3	16.5
MINERALS								
Quarts	-	27.5	-	35.6	-	34.7	-	34.5
Feldspars	-	3.4	-	3.2	-	3.2	-	6.9
Amphiboles	-	0.9	-	-	-	0.6	-	1.2
Pyroxenes	-	0.2	-	0.2	-	0.3	-	0.6
Opaques	-	0.1	-	0.9	-	0.9	-	0.3
Iron Oxides	-	0.2	-	0.9	-	1.5	-	0.6
Mica	-	0.2	-	-	-	-	-	Tr.
Garnet	-	0.4	-	-	-	-	-	0.6
Accessory Min.	-	0.3	-	-	-	-	-	-
Shell	0.4	Tr.	4.5	0.6	6.7	4.1	0.7	0.6
Coal	2.8	0.2	1.8	1.8	4.6	1.2	-	-
Wood	-	0.1	-	Tr.	1.0	-	-	0.3
Glass	-	-	0.9	2.1	0.5	0.3	-	-
Slag	3.2	0.6	0.9	-	2.1	-	-	-
Clay Lumps	0.4	-	-	-	-	-	-	-
Foundary Sand	-	-	-	-	1.0	-	-	-
	99.6%	99.9%	99.9%	100.1%	100.0%	100.0%	100.0%	99.9%
			13.5% Gravel 86.6% Sand		12.4% Gravel 87.6% Sand		23.2% Gravel 76.8% Sand	

Table 3.1

(a)

i) MAJOR ELEMENT COMPOSITION CONVERTED TO 100 %

NAME	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5	SUM
1QDA1	78.84	5.70	1.82	1.28	9.52	0.82	1.61	0.27	0.05	0.09	100
2RDM	81.28	5.85	1.75	0.74	7.49	0.89	1.62	0.26	0.05	0.07	100
3EPA	72.68	5.51	1.82	1.50	15.95	0.80	1.39	0.26	0.04	0.05	100

ii) MAJOR ELEMENT CONCENTRATIONS INCLUDING LOI* (1040 °C)

NAME	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5	LOI	SUM
1QDA1	70.05	5.06	1.62	1.14	8.46	0.84	1.43	0.20	0.05	0.10	11.91	88.96
2RDM	71.25	5.13	1.53	0.65	6.56	0.77	1.42	0.19	0.05	0.08	12.36	87.64
3EPA	66.37	5.03	1.66	1.37	14.56	1.11	1.27	0.20	0.04	0.07	8.42	91.69

iii) ANALYSES OF SOIL SAMPLES : TOTAL CARBON, SULFUR, LOSS ON IGNITION

SAMPLE	TOTAL CO_2 (%)	SULFUR (%)	LOI*(1040 °C) (%)
1-QDA1	11.56	0.05	11.91
2-RDM	12.16	0.04	12.36
3-EPA	8.22	0.04	8.42

1QDA1 = Queenston dock ; 2RDM = Red-D-Mix, Hamilton
3EPA = Presquille, Pennsylvania

(b) Niagara Bar, geochemical characteristics (From Sly, 1983)

Sector	Major Elements (per cent)										Carbon		Trace Elements (μg/g)								
	Al	Ca	Fe	K	Mg	Mn	Na	P	S	Si	O.C.	I.C.	Cd.	Cr.	Co.	Cu.	Hg	Ni	Pb.	Sr.	Zn.
$D_b + C_b$	5.88	4.02	2.40	1.66	2.35	0.05	1.19	0.12	0.03	76.9	0.68	0.87	0.85	28.6	5.4	12.7	0.95	17.3	30.7	70.2	80.4
A_l	6.63	2.99	2.36	1.85	1.73	0.05	1.34	0.09	0.02	78.4	0.38	0.63	0.84	22.9	5.5	12.1	0.67	15.8	27.1	61.7	73.0
B_l	8.68	5.56	4.25	2.29	2.84	0.09	1.15	0.21	0.13	65.2	1.99	1.23	2.10	62.5	11.3	43.4	2.92	40.6	83.7	125.	206.
C_l	11.4	4.16	6.51	3.05	3.05	0.27	0.97	0.27	0.14	58.7	3.02	0.92	3.37	90.1	16.2	78.3	4.30	67.7	157.	124.	356.

* Note: LOI-Loss on Ignition (See Glossary)

Table 3.2 Chemical characteristics of sediments of the Niagara Bar region and Presquille Pennsylvania.

material such as coarse aggregate from land-based pits, to reduce the overall amount of undesirable components below the standard requirements. After this blending process was performed by the Hydro-Electric Power Commission, no significant problems were encountered in tests which measured the maximum expansion of cement blocks and changes (none found) on concrete blocks subjected to freezing and thawing as well as wetting and drying conditions.

In one instance, surficial bumps were observed and analyzed on the surface of a concrete block floor by the Ministry of Transporation and Communications. These pop-outs were caused by the alkali-silica reaction set up by small pieces of artificial glass. Although a few other glass pieces were found in the floor, blistering was observed only at the surface of the blocks. The general low alkali content of the cement (0.65 to 0.70 expressed in Na_2O) "prevented serious reaction throughout the concrete (MTC, unpublished document)".

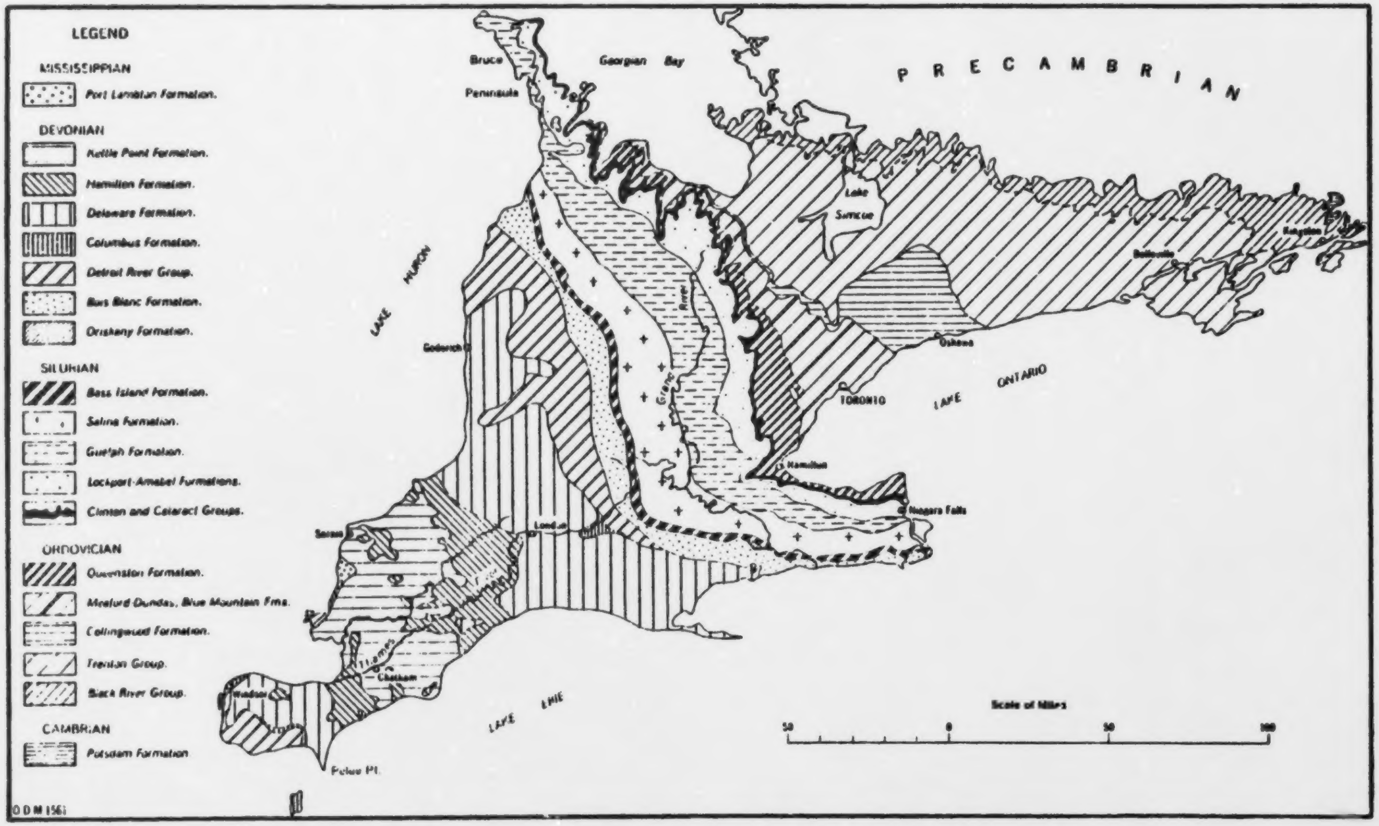
It should be noted that the presence of deleterious components in the deposit and the variation in quality from one part of the accumulation to another is not a peculiarity of the Niagara Bar, rather it is a common feature of sand and gravel deposits of the Lake Ontario Basin and other parts of Ontario, such as the Ottawa-St. Lawrence area. Large portions of the deposit at Fonthill, for instance, contain abundant amounts of deleterious components (Section 1.7.1). The presence of these materials is due to the fact that the glaciers and rivers cut into bedrock units which contained cherty materials, such as parts of the Trenton, Amabel-Lockport, Goat Island and Dundee paleozoic carbonates and, in particular, the Oriskany Sandstone (Figures 3.3, 3.15). Other types of liable material, such as mud pebbles and friable sandstone fragments were derived from the erosion of shale and sandstone units such as the Queenston and Medina Formations. "As it is a rare deposit which will satisfy most aggregate specifications, deposits of gravel must be processed by crushing, washing and screening (Proctor and Redfern, 1974).

Not all types of chert are equally alkali-silica reactive (Gillot, 1975), however, because of the high (Table 3.1) content of chert and silicified rock in the nearshore sands dredged from the Niagara Bar and off Erie, Pennsylvania. Users of these materials should carry out specific tests (National Standard of Canada) to determine whether the sands to be used are unacceptably alkali-expansive.

3.3 Reserve Estimates in the Niagara Bar

A preliminary estimate of 1.2×10^8 m^3 of sand resource for the total Niagara Bar (including both the Canadian and American portions) was made by Rukavina (in: Martini et. al., 1983). This generalized estimate was made by assuming an areal extent of sand in the order of 3.8×10^7 m^2 (where the surficial materials have a percentage of sand + gravel greater than 50 percent), and an average thickness of 3.2 m for the whole Bar.

More detailed analysis of the same data integrated with supplementary information (Sondilands and Sly, 1977; Mckeil Work Boats Ltd. and Cptn. S. Leonard,


LEGEND
MISSISSIPPIAN
Port Lambton Formation.
DEVONIAN
Kettle Point Formation.
Hamilton Formation.
Delaware Formation.
Columbus Formation.
Detroit River Group.
Bois Blanc Formation.
Oriskany Formation.
SILURIAN
Bass Island Formation.
Salina Formation.
Guelph Formation.
Lockport-Amabel Formations.
Clinton and Cataract Groups.
ORDOVICIAN
Queenston Formation.
Meaford-Dundas, Blue Mountain Fms.
Collingwood Formation.
Trenton Group.
Black River Group.
CAMBRIAN
Potsdam Formation
O D M 1561
Bruce
Peninsula
Georgian Bay
PRECAMBRIAN
Lake
Simcoe
Kingston
Belleville
Oshawa
TORONTO
LAKE ONTARIO
Hamilton
Niagara Falls
Grand River
LAKE HURON
Goderich
London
Sarnia
Thames
Chatham
Windsor
Pelee Pt.
LAKE ERIE
Scale of Miles
50
0
50
100

Regional geology of southwestern Ontario. *(After Geological Survey of Canada.)*

Figure 3.15 - Geological Map of Southern Ontario

Personal Communication) allowed a refinement of the estimate of sand resources in parts of the Niagara Bar (Figure 3.16; Tables 3.3, 3.4). For this estimate, the area of the bar was subdivided according to the average grain size of the surficial sands. The average grain size of the sand fraction is an indicator of the suitability of the material for various uses, such as fine aggregate for concrete, brick and masonry works. Where no data was available, such as at the mouth of the river, the information from dredging operators was used. Accordingly, the important source for coarse material at the river mouth could be subdivided into two parts; one containing a large amount of deleterious materials (glass, coal and slag) and a second part with less contaminated useable sediments.

The thickness of the bar deposit was estimated from jettings to refusal and information obtained from dredging operators. The values we have used for resource estimation are conservative ones, generally being taken at half the depth of the nearest jetting penetration. Justifications for this include the expectation that only part of the deposit contains a useable coarse sand resource and that the material becomes finer with depth.

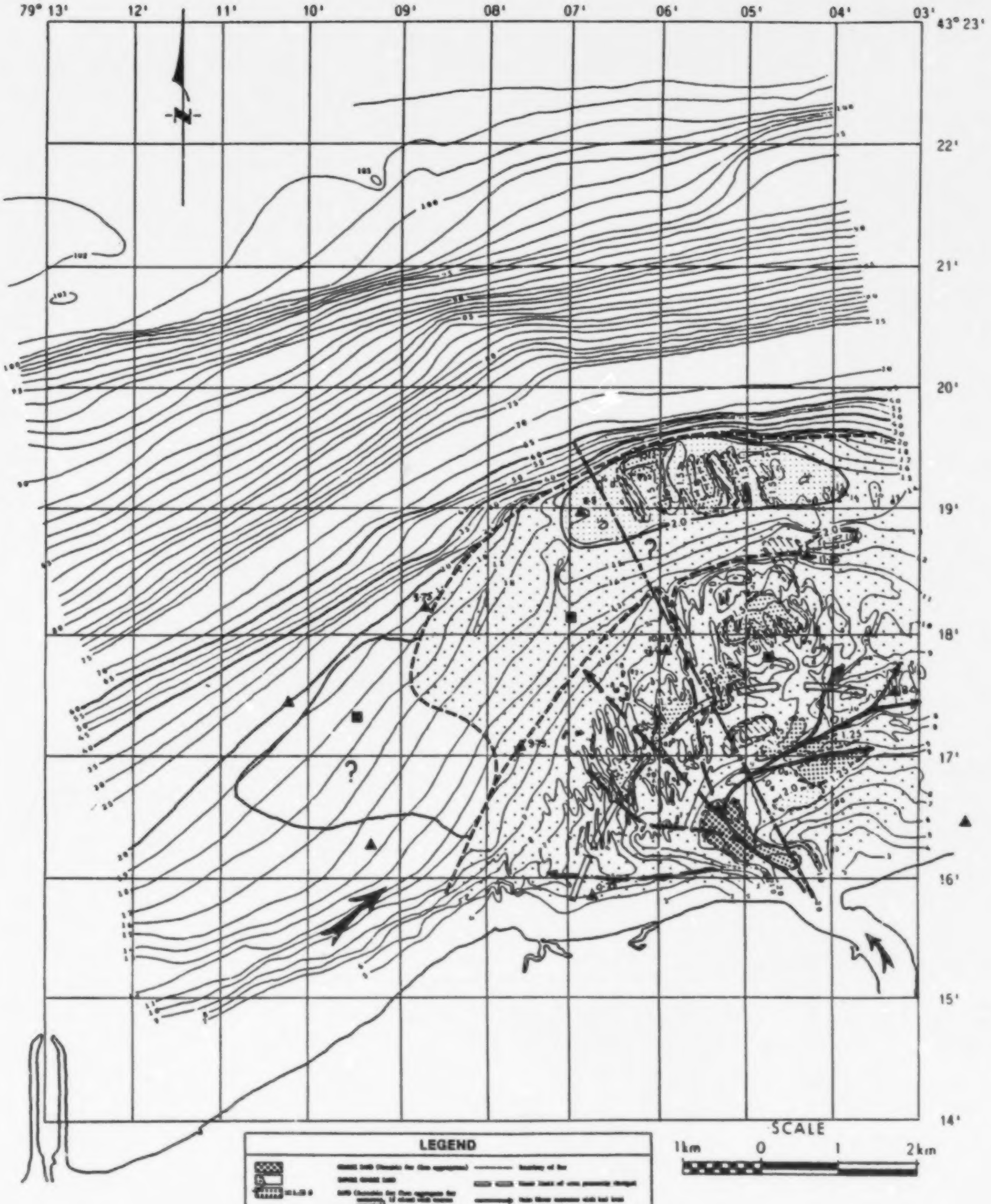
The available information suggests that a considerable amount of useable sand is available in the Niagara Bar, if dredging is extended further offshore beyond the present day 2.5 km zone of operation (see Table 3.3). However, only a small amount of sand in the bar can be used directly as fine aggregate for concrete. For this use, much of the coarse material obtainable at the mouth of the Niagara River must be mixed in a 1 to 2 proportion with other sand from the Bar (Cptn. J. Leonard, Personal Communication). This mixing can generate fine aggregates for concrete estimated in the order of 6.9 million tonnes, which is only a small proportion of the total amount present in the Bar.

All of the above estimates were based on a limited amount of information, most of which was collected for purposes other than determining the resources of the Niagara Bar. The results presented here should be confirmed with appropriately designed field sampling and testing. However, the present estimates indicate that availability of coarser blending materials can, in the long term, become a limiting factor for the dredging operations on the Niagara Bar.

3.4 Dredged Material: Production and Uses

Sand dredging in the lower Great Lakes has been in operation since the turn of the century (Figure 3.17). For instance, Erie Sand and Gravel Co. of Erie, Pennsylvania, has been active since 1898. Their Canadian operation dates back to 1969, when the M/V W.M. Eddington was purchased. The Canadian National Sand and Material Co. Ltd. also dredged sand from both Lakes Erie and Ontario from the 1930's through 1976, when it scrapped the S.S. Charles Dick. The sand sucker they used dug material from the Niagara Bar as well as from Lake Erie, off Point Pelee and along the American shore.

In the 1950's, the volume of dredged material produced from the Niagara Bar was much greater than the present, mainly because there were a number of major construction projects going on at the time such as the hydroelectric power


79° 13'
12'
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22'
21'
20'
19'
18'
17'
16'
15'
14'
N
?
?
LEGEND
SCALE
1km
0
1
2km

Figure 3.16 - Sand Resource Map of Niagara Bar

ESTIMATE OF SAND RESOURCES

EXAMPLES OF POTENTIAL USES*	MEAN GRAIN SIZE Ø**	QUANTITIES (in million of tonnes)	
		Canadian Side	American Side
Coarse fraction of concrete fine aggregate mixture.	-	2.29	-
Fine aggregate for concrete	1.25	-	2.29
Plaster sand, Potential fine aggregate for concrete (with suitable beneficiation).	1.25 - 1.5	0.93	10.43
Plaster and masonry Sand, fine portion of concrete fine aggregate mixture.	1.5 - 2.0	4.1	10.84
Plaster and masonry Sand, fine portion of concrete fine aggregate mixture	2.0 - 2.5	159.3	68.3
	TOTAL	166.62	92.49

Table 3.3 - Estimate of Sand Resources

Note: * For Areal Extent see Figure 3.16
** See Note on Phi in Glossary

ESTIMATE OF FINE AGGREGATE QUANTITIES: NIAGARA BAR

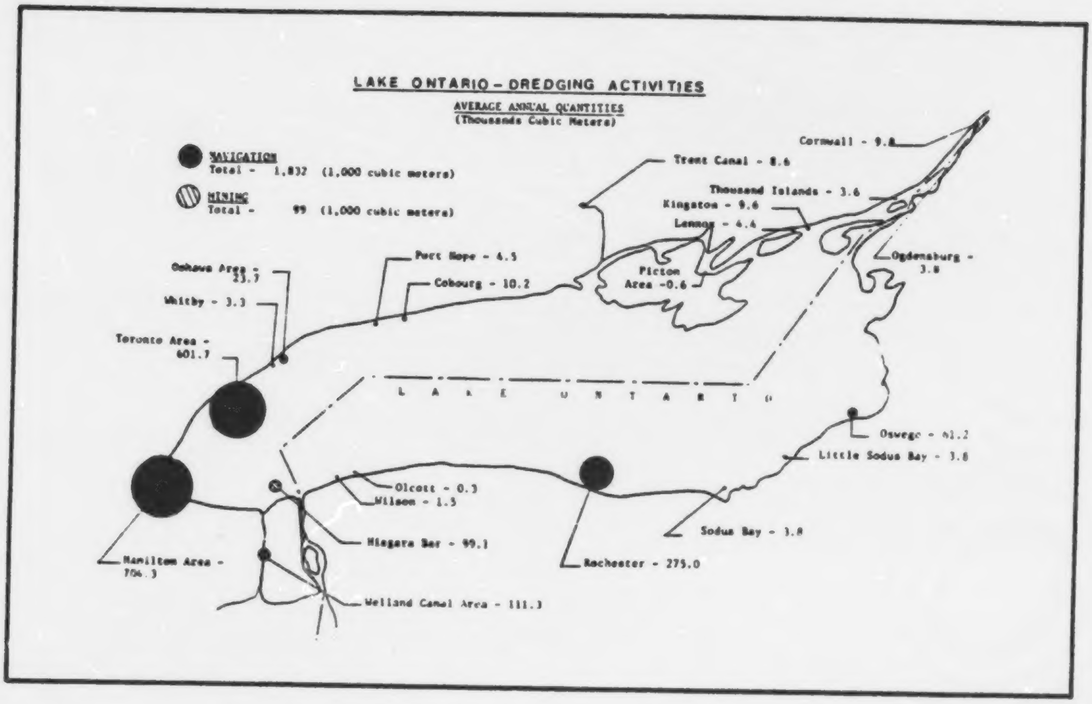
PRINCIPAL USES	Quantities(millions of tonnes)	
	Canadian side	American side
i. Concrete fine aggregate	6.87	2.92
ii. Plaster, masonry and other purposes	159.76	89.57

Table 3.4

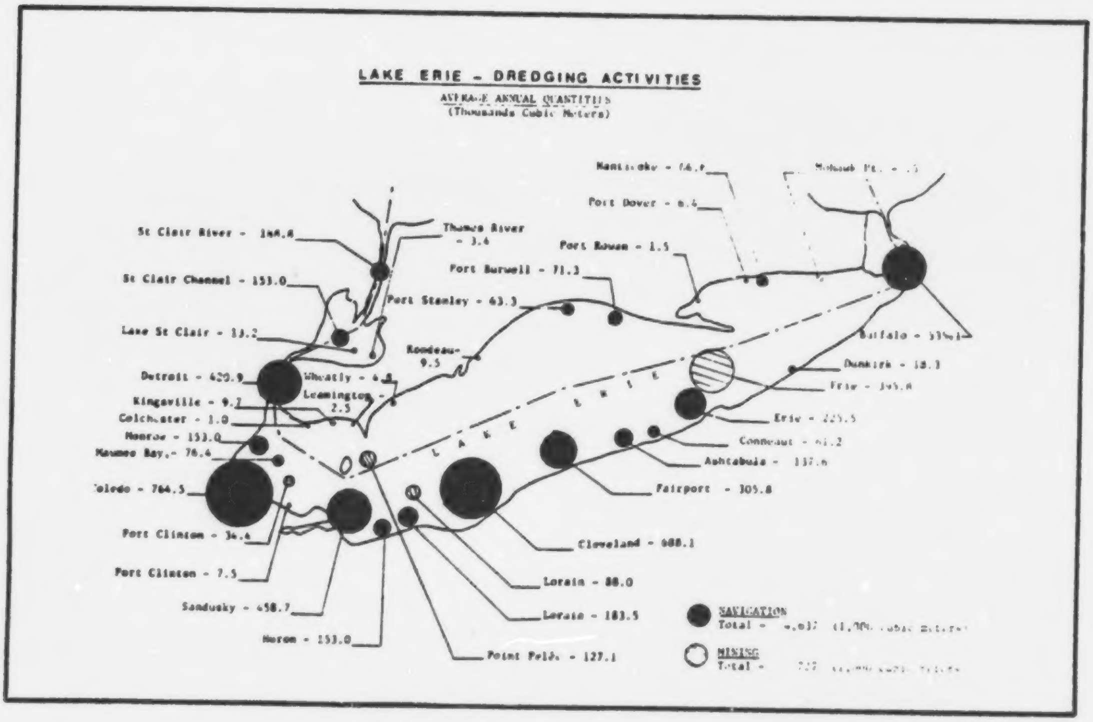
BOATS USED IN DREDGING SAND FROM THE LOWER GREAT LAKES

Boat	O.A. Dimension	Built	Dredging
M/V C.W. Cadwell	162' x37' x17'6"	Wisconsin 1911	1911-1983 Presently owned by Mckeil Works Boat Ltd. Out of service.
M/V Niagara II (Eddington)	182'6"x43'3"x13'	England 1930	1954-69 Niagara I 1969-84 Eddington, Ontario Erie Sand and Gravel Ltd. 1983-present Niagara II, Mckeil Boat Works Ltd.
SS Charles Dick	258'6"x43'3"x20'	Ontario 1922	1976 sold for scrap
SS Hydro	185'x40'6"x19'	Wisconsin 1913	1913-1962 Sunk at Erie P.A. to form part of a dock extension.
M/V Sandland	259'x42'9"x18'6"	England 1925	1925-1943 sold for off lake use.
SS Sand Merchant	259'x43'6"x20'	Collingwood 1927	Sunk in 1936 after pumping sand off Pt. Pelee.

Table 3.5


LAKE ONTARIO - DREDGING ACTIVITIES
AVERAGE ANNUAL QUANTITIES
(Thousands Cubic Meters)
NAVIGATION
Total - 1,832 (1,000 cubic meters)
MINING
Total - 99 (1,000 cubic meters)
Cornwall - 9.8
Trent Canal - 8.6
Thousand Islands - 3.6
Kingston - 9.6
Lennox - 4.4
Picton Area -0.6
Ogdensburg - 3.8
Port Hope - 4.5
Cobourg - 10.2
Oshawa Area - 23.7
Whitby - 3.3
Toronto Area - 601.7
L A K E O N T A R I O
Oswego - 61.2
Little Sodus Bay - 3.8
Olcott - 0.3
Wilson - 1.5
Niagara Bar - 99.1
Sodus Bay - 3.8
Hamilton Area - 706.3
Rochester - 275.0
Welland Canal Area - 111.3

a) Lake Ontario


LAKE ERIE - DREDGING ACTIVITIES
AVERAGE ANNUAL QUANTITIES
(Thousands Cubic Meters)
Nanticoke - 76.
Mohawk Pt. - .5
Port Dover - 6.4
St Clair River - 168.8
Thames River - 3.4
Port Rowan - 1.5
Port Burwell - 71.3
St Clair Channel - 153.0
Port Stanley - 63.3
Lake St Clair - 33.2
Rondeau - 9.5
Buffalo - 339.1
Dunkirk - 18.3
Detroit - 429.9
Wheatly - 4.8
Leamington - 2.5
Erie - 345.8
Kingsville - 9.7
Colchester - 1.0
Erie - 225.5
Monroe - 153.0
Conneaut - 61.2
Maumee Bay - 76.4
L A K E E R I E
Ashtabula - 137.6
Toledo - 764.5
Fairport - 305.8
Port Clinton - 34.4
Cleveland - 688.1
Port Clinton - 7.5
Lorain - 88.0
Sandusky - 458.7
Lorain - 183.5
Huron - 153.0
Point Pelee - 127.1
NAVIGATION
Total -
MINING
Total -

b) Lake Erie

Figure 3.17 - Dredging Activities

stations along the Niagara Gorge. A number of boats were working on the Niagara Bar then including the "Niagara" (formerly called the "Eddington" and now called the "Niagara II"), the "Charles Dick", "Sandiland" and the "Cadwell" (see Table 3.5).

The dredged sand was delivered by boat and by truck to Toronto, Hamilton, the Queenston dock and to New York State. The production of dredged material from the Niagara Bar varied according to its changing competitiveness with materials derived from land-based sources. One advantage of the dredged sand during periods of high fuel prices, was and still is, its lower delivery cost to major urban centres like Hamilton. In the last 10 to 15 years, the production of material has fluctuated from a high of 318,900 tonnes in 1973, due to demand by a major local project (ie. the extension of the Queenston power plant) to low figures of 66,000 tonnes (Regional Niagara, 1981; Table 3.6). A similar, although not as great, recent decline in production of sand and gravel has been registered also from the land-based pits at Fonthill and for the aggregate industry within the Region (See Figure 1.5) in general. This indicates an overall reduced market demand for aggregates in the Region.

Historically, dredged material from the Niagara Bar has been used for the manufacturing of bricks (Harbour Brick Co. of Toronto in the 1920's to the 1970's Cptn. J. Leonard, Personal Communication), concrete sand, apshalt sand, granular fill, masonry sand, block grit for concrete blocks, winter sand and for pH control at green nurseries. The dredged material from the Niagara Bar has been used successfully as a fine concrete sand in major projects such as the extension of the Queenston power plant, the Sir Adam Beck Generating Station (in exposed and non-exposed concrete in the power house, cliff facing and in the tunnel), the Burlington Skyway and a variety of high rise buildings and road construction in the Hamilton area.

The Bar presently provides 18 to 20 percent (Figure 3.18) of all fine aggregates produced in the Region, the sand regularly being used as part of the fine aggregate component of ready-mix concrete such as that produced by Standard Aggregates (Red-D-Mix) in Hamilton (Table 3.7).

3.5 Constraints and Opportunities for the Dredging Industry

During recessive market conditions, several factors become critical for a profitable sand dredging operation. These factors include:

- increased production costs
- licensing rules
- quality of materials
- quantity of materials

DREDGED SAND PRODUCTION
(Tonnes)

Year	Total in Niagara
1972	147,300
1973	319,000
1974	177,300
1975	152,400
1976	130,300
1977	71,600
1978	90,500
1979	99,500
1980	94,900
1981	95,600
1982	66,000
1983	66,800
1984	67,315

Table 3.6

DREDGED SAND FROM THE NIAGARA BAR SUPPLIED TO RED-D-MIX IN HAMILTON

Year	Tonnage (Tonnes)*
1978	36,000
1979	50,000
1980	41,000
1981	65,000
1982	35,000
1983	40,000
1984	40,000

* represent half of Red-D-Mix use in Hamilton

Table 3.7

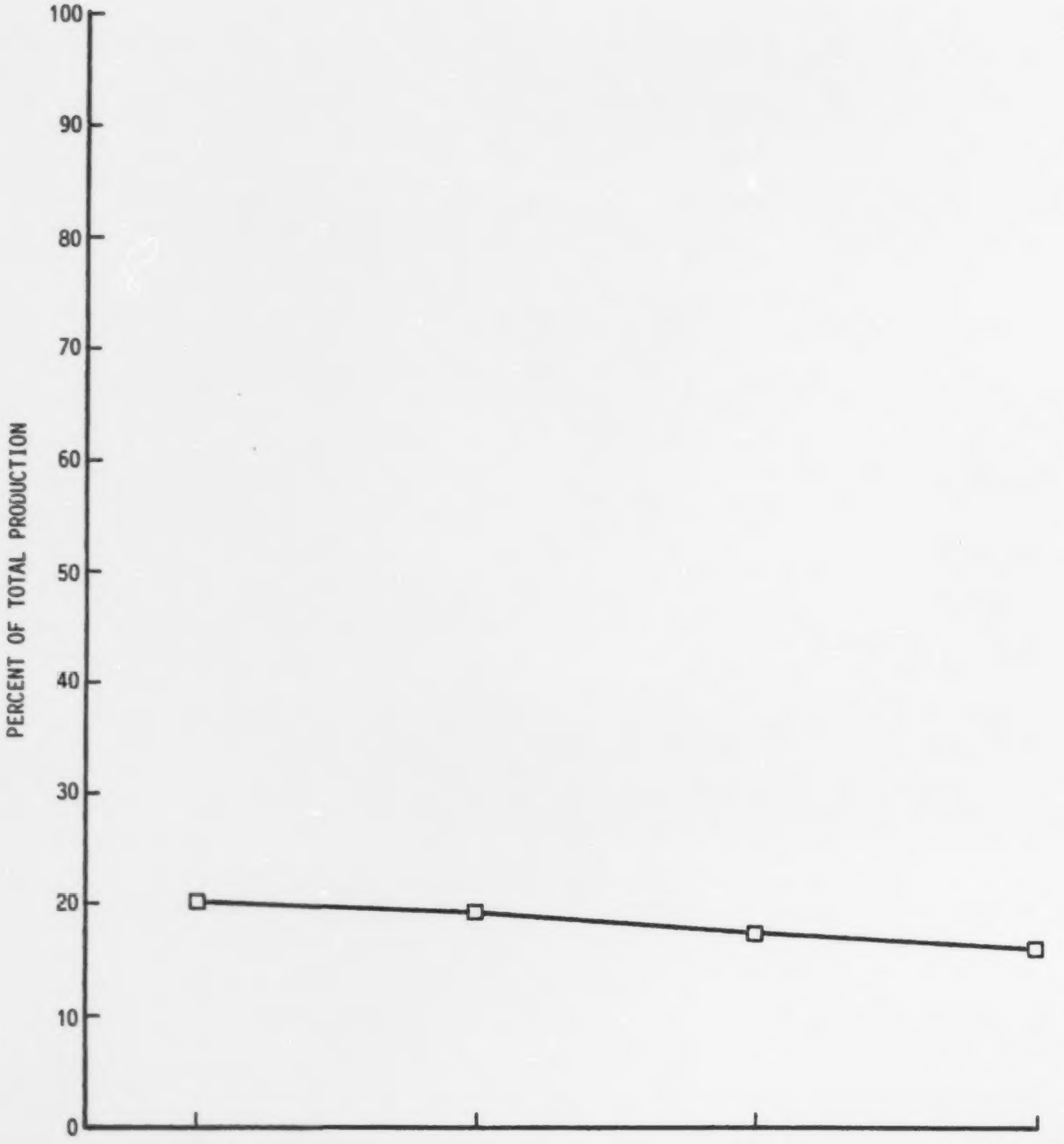


Figure 3.18 - Percentage of Total Production of Fine Aggregates Satisfied by Dredging

3.5.1 Production Costs of Material From the Niagara Bar

A portion (about 40 to 50 percent) of the sand dredged from the Niagara bar is at the present delivered by the dredging operator (McKeils Works Boat Ltd.) to the Hamilton dock. The remainder is delivered to the Queenston dock for a lower price due to the shorter hauling distance. These rates have been calculated to include approximately 20 percent gross profit as well as direct costs of 14.3 percent for royalties to the Ontario Government and 64.27 percent for other expenses including:

- wages for 6-7 non-unionized workers
- food for crew
- fuel and lubricants for boat
- cables and other maintenance items

The sand delivered to Hamilton is used directly by the buyer (Red-D-Mix). All sand delivered to the Queenston dock is re-sold at $5.28 per tonne by a marketing firm (Bawtinheimer Ltd.). At the moment there is no price difference between the two types of products provided at the dock (concrete and brick sand).

Future changes that the dredging operator may have to face if the market expands significantly, may be competition by other operators as well as possible higher costs for the workforce.

3.5.2 Institutional Factors

One of the major constraints for the dredging industry is the high cost of royalties. In 1984, the rates were $.33 per tonne, which is double that of the royalty rate fixed in previous years. This cost is apparently much higher than the security deposit required from land-based operations (currently pegged at $.08/tonne).

Until recently, a major drawback for dredging operations was the one year duration of the renewable provincial licence. Since 1983, this difficulty has been removed and the licenses now run up to five years. In comparison the licenses on the American side run for three years. However, it is the opinion of present dredgers that the renewable licence should be about ten years to justify the high capital investment necessary for this industry.

Federal permits for docking do not appear to be a constraint for the industry. The limited availability of proper natural areas for docking may be a stronger limitation for any significant future expansion, however, possible use of a slurry pipeline system may overcome the need for larger docking facilities (see Section 3.5.4).

A major constraint to the development of markets for the dredged material from the Niagara Bar in the past has been the perceived unsuitability of the material by some of the more major provincial users such as the Ministry of Transportation and Communications. In effect the standards used by such an organization do not differ from those of other major users in Ontario.

3.5.3 Quality and Quantity of Material

The quality and quantity of dredged materials has been analyzed previously. Neither one appears to be an insurmountable constraint for the dredging industry, at least for the production of specific products. Although deleterious material is present in the deposits (Table 3.1), reasonable blending and processing can overcome such problems. The dredged material can be successfully utilized as the fine component for concrete as it is now used by Red-D-Mix of Hamilton and it has been used in the past in major hydroelectric projects in the Region (Appendix IV).

The problem is not so much in the quality of the material per se, rather in the expectation that the dredged sand obtained directly from the boat can be used without further processing. This is an unrealistic expectation, contrary also to common practices in the majority of the land-based pits. Sufficiently large stockpiles and unloading facilities are two of the main pre-requisites for maintaining a desirable consistency in quality. Adaptation of new technologies such as the "Bucket Wheels" dewatering and sorting procedures may improve the quality of the dredged material as well (Basic Structure, 1981).

A possible future limitation for dredging the Niagara Bar is the limited availability of fine aggregates for concrete. Assuming that the coarsest fraction similar to that occurring at the mouth of the Niagara River is non-renewable, nor is imported from other sources, and that future demand will be similar to that of the past, it has been estimated that the 6.9 million tonnes of fine aggregate retrievable from the Bar can supply the market, for a duration varying from 20 and 100 years (Table 3.8).

3.5.4 Docking Facilities

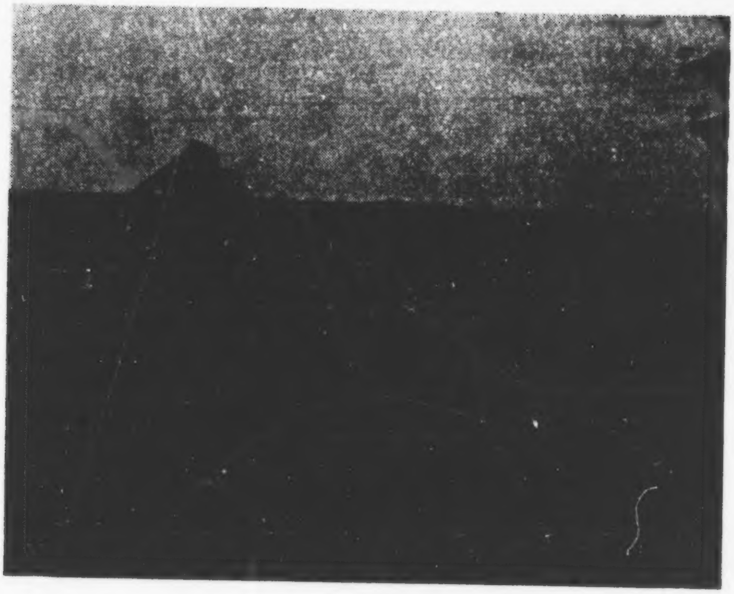
Along the Lake Ontario shore, there are few suitable facilities for unloading of bulk quantities of aggregates. This may be a major constraint for an expanding dredging industry. The docking facilities at Queenston are minimal for a limited enterprise. Those facilities do not provide enough space for stockpiling different materials nor have facilities to blend the dredged sand with land-derived products. Similarly, it is difficult to find good docking facilities which have not yet been already occupied by yacht clubs or that do not occur in urban areas. Should the market justify them, new areas will need to be developed or artificial docks constructed at suitably located sites proximal to the major markets. Under such circumstances, a major study would be required on the pertinent characteristics of the southern nearshore of Lake Ontario, and on the availability and cost of sites to locate suitable docking facilities.

The experiences of one user as well as a producer indicate that to be successful, a docking, storage and mixing facility would require a minimum of 20 acres and it should be equipped with suitable blending equipment (Figure 3.19). It has to be noted that past large users of sand from the Niagara Bar, such as the Ontario Hydro-Electric Power Commission, established their own large stockpiles at the locations or vicinities of the power stations, such as Sir Adam Beck and at Decew Falls.

SUMMARY OF SAND PRODUCTION

	(A) Annual sand production(between 1972-1984) (in thousands of tonnes)	(B) Duration of existing resources (No. of years)
Lowest(1982)	66.0	104.1
Average	122.5	56.1
Highest(1973)	319.0	21.5
1984	81.8	84.0

Table 3.8



A. Dredged sand and ready-mix concrete operations, Erie Sand and Gravel Co. Ltd., Erie, P.A.

B. M/V/ Lakewood, 4200 ton capacity (Nov. 1984, Erie Sand & Gravel Co., P.A.)

Figure 3.19 - Photographs of Dredging Operation at Erie, Pennsylvania

The possible use of slurry pipelines to recover sand from the Niagara Bar may alter the need for docking space to that of the storage area, which can be located some distance from shore. This alternative may require the allocation of right of way for the pipeline itself, construction of caissons-type mooring in the nearshore, and the use of jacked-up or floating rigs at specific mining locations. Heavy seas and freezing conditions limit sand recovery to a 9 months operation. It is suggested that an increased demand of about 100,000 cubic yards per year is needed to justify this investment (Bawtinheimer Ltd., Personal Communication).

3.5.5 Existing Producers: Niagara Bar and Lake Erie

At the present time, only one dredging operator is active in the vicinity of the Niagara Region. Historical records indicate that more operators can profitably work the Niagara Bar if market conditions become more favourable.

The probability of success of dredging operations in Lake Erie in the proximities of the Region is limited. Dredging in the past has been carried out in the Mohawk Point area. However, the material available there consists of very fine sand which could only be used for general purposes (such as fill) and is not suitable for concrete.

Production of a variety of materials, including fine concrete sand, asphalt sand and masonry sand can be produced from other areas of Lake Erie, both along the Canadian and American coasts. In the past, dredging has been active in the Point Pelee area and Long Point. Two dredging operators are still active at several sites along the American coast (Figure 3.19). Large quantities of sand for various uses can be readily obtained from places such as offshore Erie, Pennsylvania. A price of $5.87 per tonne is however required because of the long haul to a docking site on the Lake Erie coast of the Region. The opinion of the major American operator (Erie Sand and Gravel Co.) is that it would not be economically feasible to transport the sand to the Lake Ontario shores using the Welland Canal. Two main reasons were given for this. One relates to the tolls required, and the second relates to possible long delays barges may encounter in crossing the canal due to heavy shipping traffic. To overcome this second constraint, a large financial investment would be required for acquisition of additional barges to run an effective dredging and transport operation.

3.5.6 Environmental Concerns

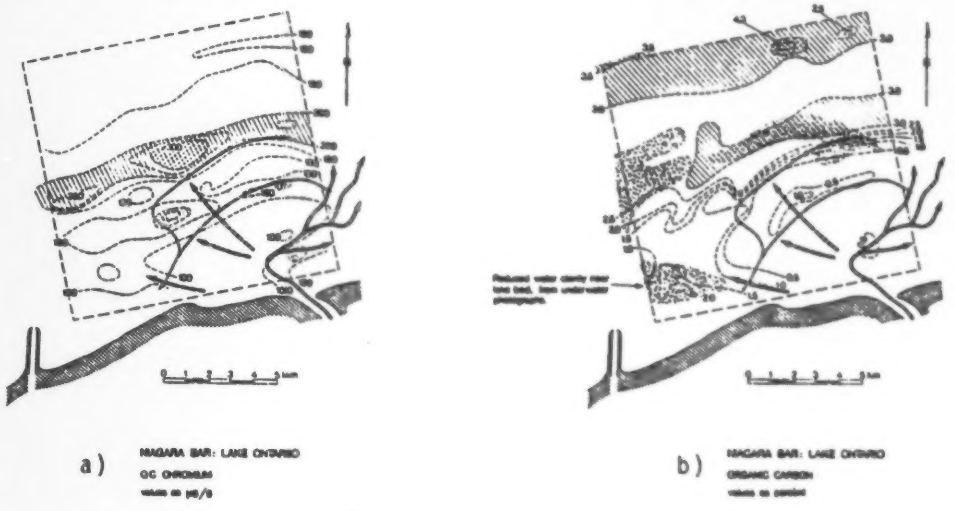
Considerable work has been done on determining the concentration of elements in the Great Lakes and the Niagara River (Allen et. al., 1983; Kaminsky, 1983; Thomas, 1983; Sly, 1977, 1983a, 1984).

Sly (1983a, 1983b, 1984) indicates that, whereas the distribution of most major and minor elements can be related to the distribution of natural materials along the main river channel and over the bar (Figure 3.14, Table 3.2B), some of the metals such as Hg and other elements concentrated in the silt fraction of the deposits may be anthropogenic. Elements such as Ca, S, Organic Carbon, Cr and Hg are good natural tracers and their distribution aids in mapping the dispersal pattern of the fluvial plume (Figure 3.20). Accordingly, it is clear that the coarse material is transported as bedload only along the floor of the river channel. Part of the suspended material can cross the bar along furrows (Figure 3.3). The major component of the suspended material, however, is transported along the main channel of the river. It travels eastward and as it exits, the material is caught by a westward gyre caused by the influence of the Bar which redistributes the sediment along the lakeward margin of the outer bar (Figure 3.3).

The effect of dredging coarse material on chemical pollution of the lake is considered to be minimal, primarily because the Bar itself is not a major sink of contaminants (elements). The chemical contamination that is derived from the release of interstitial waters during dredging has only a local and temporary(usually less than one week) effect on the environment (Sly, 1984).

Most of the fine materials are transported into deeper waters by the fluvial plume and lacustrine currents. Nevertheless, some silt and clay (10 percent or generally less) is retained in the bar and is released during the dredging operation. Not much is known about the "sediment pollution" generated by a dredging operation of the kind active in the Niagara Bar, but unless the amount of dredging increases greatly, it is difficult to see how it can generate a severe pollution problem. The amount of material put in suspension by dredging, although it may be locally concentrated, is quantitatively insignificant with respect to the amount placed in suspension during a natural storm (Sly, 1984).

There is no specific information on the use, if any, of the Niagara Bar by spawning fishes. The removal of sand, the continuous local turbid waters and the resultant sealing of surface porosity of granular material may be harmful to the fish. However, the dredging activity can be regulated such that dredging is not concentrated on areas best suited for fauna development, or timed not to interfere with migration and spawning periods. Under these circumstances, dredging is not considered to greatly create pollution problems, nor modify significantly the shallow coastal environment.

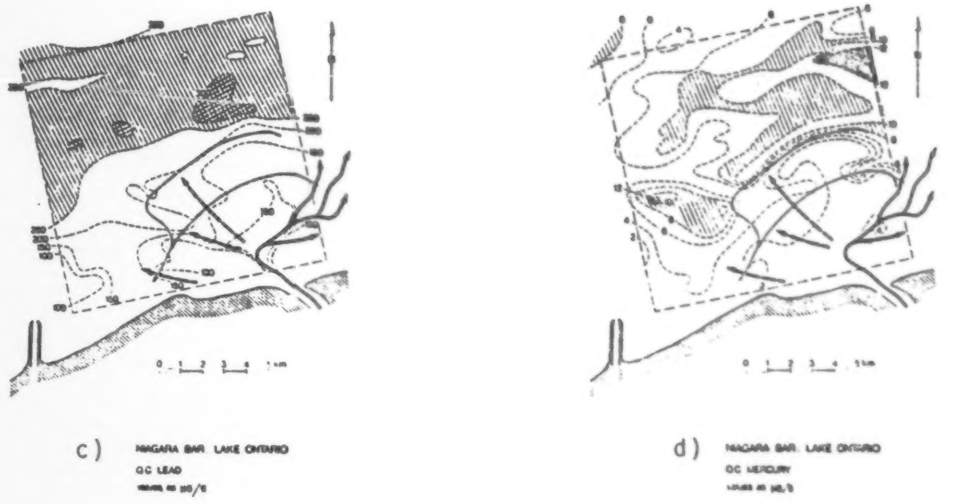


a) NIAGARA BAR: LAKE ONTARIO
QC CHROMIUM
values as µg/g

b) NIAGARA BAR: LAKE ONTARIO
ORGANIC CARBON
values as percent

Niagara Bar, Lake Ontario: Distribution of quartz corrected chromium.

Niagara Bar, Lake Ontario: Distribution of organic carbon



c) NIAGARA BAR: LAKE ONTARIO
QC LEAD
values as µg/g

d) NIAGARA BAR: LAKE ONTARIO
QC MERCURY
values as µg/g

Niagara Bar, Lake Ontario: Distribution of quartz corrected lead.

Niagara Bar, Lake Ontario: Distribution of quartz corrected mercury

Figure 3.20 - Distribution of a) Quartz Corrected Chromium
(Sly, 1983a) b) Organic Carbon
c) Quartz Corrected Lead
d) Quartz Corrected Mercury

4.0 CRUSHED STONE AND MANUFACTURED SAND FROM QUARRIES

4.1 Introduction

Crushed limestone and dolomite from quarries is the major source of aggregates within the Niagara Region. The location of the primary producers of these products is shown in Figure 1.2 and on Drawing No. 1 in the pocket at the back of this Report.

Screenings, stone dust or crushed fines are a by-product when quarried rock is processed for the purpose of obtaining the coarse aggregate sizes (Kalcheff and Machemehl, 1980). Manufactured sand, on the other hand, is a general term used to describe quality controlled, processed, fine aggregate produced from screenings by readily-available crushing or size reduction equipment along with mechanical (water or air) classification systems to separate out unwanted sizes (Kalcheff, 1977).

4.2 Production From Quarries

The total production of crushed stone products from quarries within the Niagara Region has fluctuated from approximately 2.8 to 5.2 million tonnes during the 1970's and early 1980's but has steadily declined during the last dozen years (see Figure 1.3) (as has production from other sources). However, the total production produced by quarries on a percentage basis within the Region has steadily increased over the same period from approximately 70 percent in 1972 to 82 percent in 1983 (see Figure 1.4). This is very significant since the percentage of total production from all other sources (and particularly the Fonthill Kame) has steadily declined from 1972 to 1983.

While quarries currently provide most of the total aggregate production within the Region, this is not the usual case in most areas of Ontario. Quarries provide only about one-third of the total aggregate production in Ontario. This trend was also very evident in a survey carried out by the Ministry of Transportation and Communications (Regional Niagara, 1981, p.41). That study showed that, in the Central Region of Ontario (which includes the Niagara Region), approximately 67 percent of aggregates used in road construction was from sand and gravel pits, while only 33 percent came from quarries.

On the other hand, a study by Regional Niagara (1981) showed that only 10 percent of aggregates used in roads in the Niagara Region came from pits, while 90 percent came from quarries. That study also showed that aggregates from quarries represented approximately 86 percent of the consumption by municipalities within the Region while only 14 percent came from pits (Regional Niagara, 1981).

The Region is a net exporter of construction aggregates and approximately 1 million tonnes of crushed stone products is exported to the United States through Port Colborne.

These statistics clearly illustrate that the Niagara Region has relied on aggregates produced by quarries in the past and will continue to do so as sources of natural sand and gravel of acceptable quality within its borders become depleted.

4.3 Products Currently Being Produced From Quarries

A wide range of products are currently being made from crushed stone within the Niagara Region including granular base and subbase, concrete products, asphalt sand and winter sand.

Figure 4.1 shows that over the years 1980 to 1983, quarries accounted for greater than 95 percent of clear aggregates ranging from 1/4" (6mm) to 2" (50mm) and larger, 90 to 100 percent of coarse aggregates, 20 to 25 percent of fine aggregates, 55 to 85 percent of granular base and subbase and approximatly 75 percent of all other aggregate products produced in the Region.

Quarries provide virtually 100 percent of asphalt stone and screenings, approximately 80 percent of Granular "A" and 20 percent of Granular "B".

Manufactured sand is used mainly for asphalt blending sand, winter sand, concrete sand and block sand. Quarries provide approximately 30 percent of the asphalt sand as well as 90 percent of the winter sand required by Regional Niagara and the local municipalities.

4.4 Potential Range and Uses of Products

Although a fairly wide range of products are currently being provided by quarries within the Niagara Region, other products which could also be produced include fluxing agents (from the Guelph / Lockport Dolomite) for the metal, glass and cement industries, sewage filter beds and in finer forms as poultry grit, stucco and the manufacture of lime (Telford and Narain, 1977). As local markets improve or traditional suppliers of these products decline, expansion of the existing product line within the Region can and will occur.

Quarries presently supply coarse aggregates for concrete products but, as mentioned previously, the Fonthill Kame presently supplies most of the fine aggregates required as 'concrete sand'. Quarries within the Niagara Region do provide approximately 50,000 tonnes of fine aggregates (as screenings) for the production of many concrete products including blocks, bricks and ready-mix.

4.5 Geology and Engineering Properties of Stone in Niagara

The Niagara Peninsula represents the eastern fringes of a large basin which covers all of the State of Michigan, parts of Indiana and Ohio and all of southwestern Ontario (see Figure 4.2).

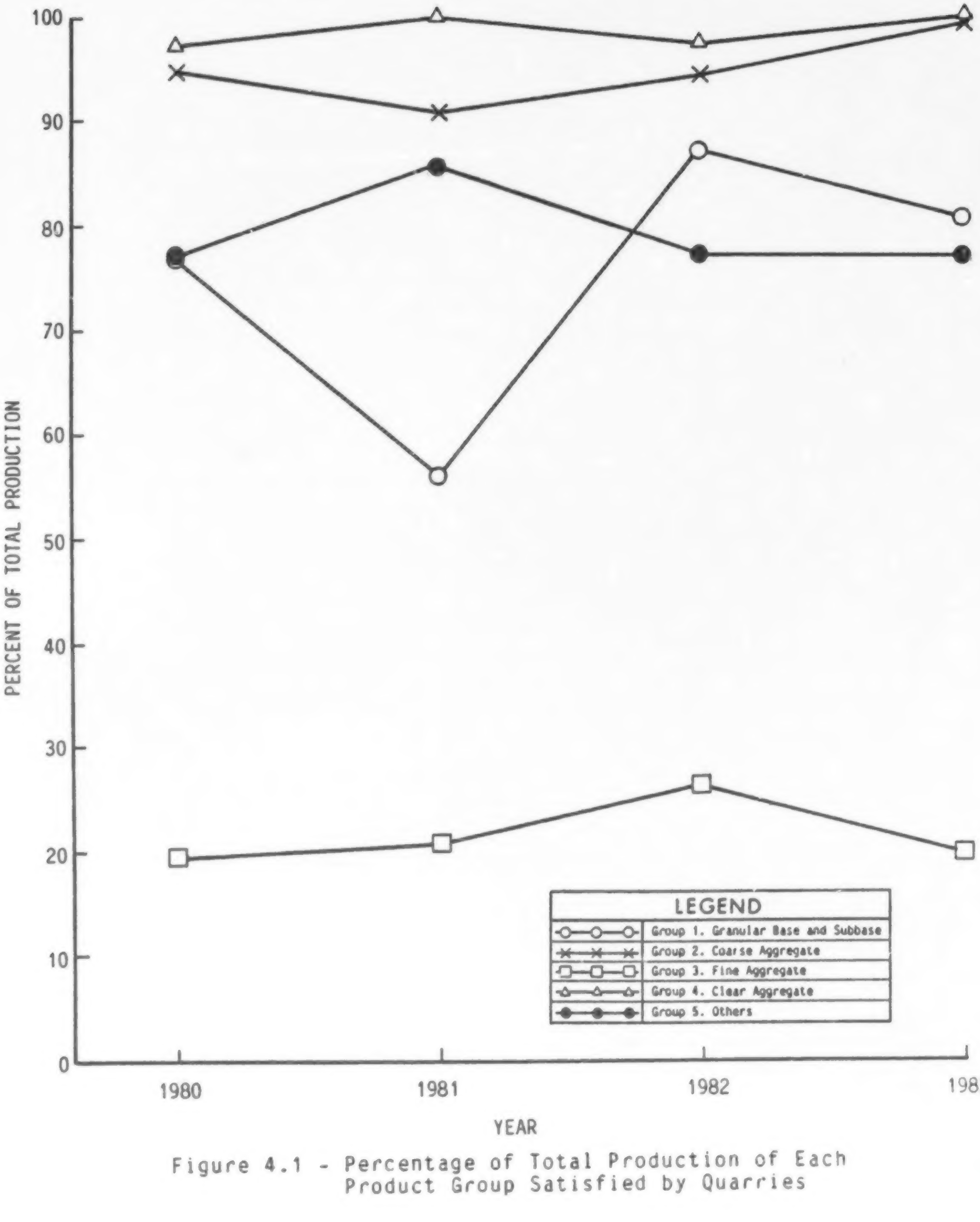


Figure 4.1 - Percentage of Total Production of Each Product Group Satisfied by Quarries

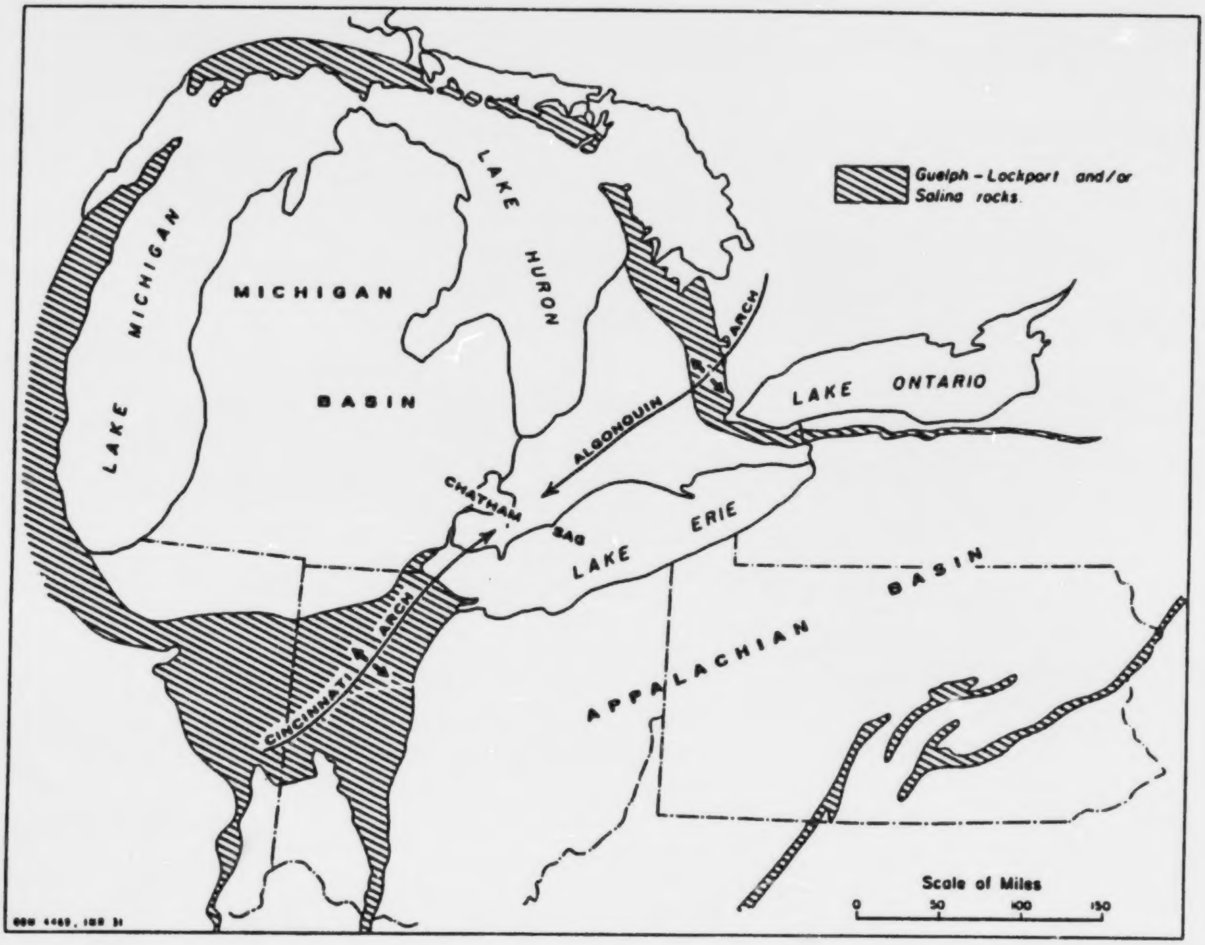

Guelph - Lockport and/or Salina rocks.
LAKE MICHIGAN
MICHIGAN
BASIN
LAKE HURON
LAKE ONTARIO
ALGONQUIN
ARCH
CHATHAM
SAG
LAKE ERIE
CINCINNATI
ARCH
APPALACHIAN
BASIN
Scale of Miles
0
50
100
150

Figure 4.2 - Distribution of the Guelph - Lockport and / or Salina Rocks in the Michigan Basin (from Vos, 1969)

Crossing the northern Niagara Peninsula in an east-west direction is the well-known Niagara Escarpment which is the most prominent physiographic feature in the Peninsula. Although, it attains a height of about 84 m above the Iroquois plain near Grimsby; east of the Town, its relief is somewhat subdued due to the broad, sloping, bedrock bench existing between the escarpment and the ancient Lake Iroquois shoreline (OGS, in press).

Another feature parallelling the Escarpment but approximately 25 kilometres to the south is the Onondaga Escarpment formed from erosion resistant dolostone of the Bertie Formation.

The near-surface sedimentary rocks prevalent in the Region consist of Silurian and Devonian limestones, dolostones, sandstones, shales and evaporites; the most important being the Niagaran Series (see Figure 4.3).

The Niagaran Series of Silurian age (which includes the Lockport-Amabel and Bertie Formations) and the Bois Blanc Formation of Devonian age predominantly consist of relatively flat-lying limestones and dolostones which regionally dip toward central Michigan. It is within these formations that most of the commercially-extractable reserves of crushed stone lie.

Each of the formations exposed or available for extraction in the Niagara Region along with the engineering properties of the rock types present are given in Appendix VII. This information has been synthesized into the Aggregate Suitability Chart shown in Figure 4.4. Since formations vary laterally as well as with depth, this chart should only be used as a guide. Detailed testing of the suitability of a particular formation should precede the application of the material for any aggregate product.

4.6 Reserves of Suitable Limestone and Dolostone

In the Niagara Region there are approximately 230 - 270 million tonnes of licenced reserves (OGS, in press) of suitable rock for aggregates remaining in presently licenced areas. Of this, approximately 108 million tonnes is suitable for concrete fine aggregates (assuming 100 percent of the Goat Island and Gasport members of the Lockport-Amabel Formation and the upper 4 m of the Bertie Formation are suitable). Most of the reserves lie in 2 bands running east/west and adjacent to the brow of both the Niagara and Onondaga Escarpments. South of the Niagara Escarpment, quarrying takes place in the Lockport (3 members) and the Decew Formations, while south of the Onondaga Escarpment most production comes from the Bertie and Bois Blanc Formations (Proctor and Redfern, 1974). Production is also possible from the Onondaga Formation but it is less desirable since it is quite variable and often has many impurities.

Recent work (preliminary only) by the Ministry of Natural Resources (OGS, in press) has defined the selected bedrock resources within the Niagara Region which reside outside of presently licenced areas, urban area boundaries and the Niagara Escarpment Development Control Area. Selection of these resources was based on the following criteria:

			Formation	Member
(Middle Devenian)			Onondaga	Moorehouse Edgecliffe
			Bois Blanc	
(Lower Devenian)			Oriskany	
(Upper Silurian)			Bertie	
			Salina	
Niagaran Series (Middle Silurian)	Albemarle Group		Guelph	
			Lockport	Eramosa Goat Island Gasport
	Clinton Group	Upper	DeCew Rochester Irondequoit	
		Mid.	▨	
		Lower	Reynales Neahga Thorold	
Alexandrian Series (Lower Silurian)	Cataract Group		Grimsby Power Glen Whirlpool	
(Upper Ordovician)			Queenston	

Figure 4.3 - The Lower Silurian to Middle Devonian Series in the Niagara Falls - Hamilton area (Modified after Vos,1969)

SUITABILITY OF LIMESTONE FORMATIONS IN THE NIAGARA REGION
FOR VARIOUS AGGREGATE PRODUCT TYPES

	GROUP 1	GROUP 2		GROUP 3			GROUP 4	GROUP 5
Formation	Granular Base and Subbase	Coarse Aggregates for Portland Cement Concrete	for Hot Laid Mix	Fine Aggregates for Portland Cement Concrete	for Hot Laid Mix	for Ice Control	Clear Stone	Others
Decew	R^1	N	R^1	N	N	R^1	R^1	Natural Cement, Rock Wool Building Stone
Lockport:								
Gasport	X^2	X^2	X^2	X^2	X^2	X^2	X^2	Gabion Stone, Flux Stone Building Stone
Goat Island	X^3	X^3	X^3	X^3	X^3	X^3	X^3	Armour Stone, Metallurgical Stone
Eramosa	R^4	N	R^4	N	N	R^4	R^4	
Bertie - Akron	X^5	R^6	X^5	R^6	X^5	X^5	X^5	Armour Stone, Rubble, Rip Rap
Bois-Blanc	R^7	N	R^7	N	R^7	R^7	R^7	Rip Rap, Rubble
Onondaga	R^8	N	R^8	N	N	R^8	R^8	Rip Rap, Rubble

NOTES: X = Acceptable R = Restricted Use N = Not Acceptable

1 Generally unsuitable but small amounts may be mixed with Lockport
2 Generally acceptable but some small soft sections with high $MgSO_4$ losses do occur
3 Generally acceptable but some lateral lithological variations can occur (including high chert content)
4 Lateral lithological variations including local development of shaley facies as well as high gypsum and chert content severely restrict its use
5 Lower 4.5 m and upper 4 m acceptable but 3 m in the middle of the formation is very argillaceous
6 Only upper 4 m of the formation is acceptable
7 Chert content can be extremely high, particulary in the lower 3 m of the formation
8 Can be quite argillaceous and cherty in some areas

Figure 4.4

1) Overburden Thickness - Only those areas where overburden was less than 8 m (25 feet) were considered to be presently extractable resources. Areas with overburden between 8 and 15 m (25 to 50 feet) thick could be considered in some circumstances but generally resources at depths this great were not considered economically extractable at this time.

2) Quality and Quantity Considerations - Only the formations of both suitable quality and quantity (taking into account environmental and other constraints) were considered as possible aggregate resources. These formations are given below.

   i) The Lockport Formation including the Gasport, Goat Island and the Eramosa

   ii) The Bertie Formation

   iii) The Bois Blanc Formation

   iv) The Decew Formation (only considered because it quite often must be quarried to obtain the more important Lockport Formation underlying the Decew)

   v) The Onondaga Formation (The Edgecliffe member and to some extent the Clarence member)

3) Cultural and other constraints - Constraints such as urban areas, parkland, fisheries and other environmental constraints were then applied to the areas defined by 1) and 2).

Once the aerial extent of the possible resources in an area (except for presently licenced areas, areas within urban area boundaries and the Niagara Escarpment Development Control Area) was established, assumptions regarding maximum extractable thickness were made and tonnage reserve estimates established. Drawing No. 2 included in the back pocket of this Report shows all possible extractable resources in the Niagara Region (excluding cultural constraints) as determined on a preliminary basis by the Ministry of Natural Resources (OGS, in press).

These extractable resources cover an area of approximately 15,100 hectares and contain 6.12 billion tonnes of unlicenced reserves.

A reserve estimate of the quantity of limestone suitable for concrete fine aggregates was also carried out using tabulations prepared by the Ministry of Natural Resources (OGS, in press). However, this assumes that the capability for manufacturing sand is fully developed. The estimate was carried out much the same way as described above but only the Goat Island and Gasport Members of the Lockport-Amabel Formation and the upper 4 m of the Bertie Formation were considered suitable for concrete fine aggregates. Assuming 100 percent of this material would be available (ie no wastage), approximately 3.3 billion tonnes of presently unlicenced reserves would be available for this purpose if they did become licenced. The lower 4.5 m of the Bertie Formation could also be used for concrete fine aggregates but because of its relatively high bitumen content, it requires extra washing to remove adhering fines. In addition, its dark colour will not allow the rock to be used for exposed concrete (a white concrete is more aesthetically pleasing). If this lower 4.5 m is also considered, an additional 360 million tonnes could be added to the reserve estimate.

4.7 Current Problems of the Crushed Stone Industry in the Region of Niagara

There are two major types of constraints which hinder or limit the Crushed Stone and Manufactured Sand industry in the Niagara Region from reaching its full potential. These include:

- Governmental Regulations
- Quality Constraints

A number of regulations have arisen from the relatively close proximity of some quarry operations in Ontario to the well-known Niagara Escarpment. Although the Escarpment is the feature most responsible for the abundance of suitable limestones and dolostones for aggregate production in the Region, it is also a rich mosaic of forests, cliffs, hills, waterfalls, scenic viewpoints, unusual rock formations (MTEIGA, 1973) and abundant flora and fauna, some of which are unique to this feature. This has understandably raised environmental concerns over its future as a vital part of our own natural heritage and has resulted in regulations limiting quarry development in the area.

The quality of certain limestones and dolostones in the Niagara Region has been found to be somewhat poor and therefore unsuitable for certain aggregate products. For example, parts of the Bois Blanc and Decew Formations tend to be quite cherty and alkali reactive which causes Portland cement concrete to expand and buckle (Ramachandran et. al., 1981). Therefore, these formations may be considered unsuitable for concrete aggregate and qualified inspectors must monitor the quarrying and crushing of aggregates in these cherty formations (Emery and Drysdale, 1976). These problems have been taken into account in the quantity estimates determined in Section 4.6.

Manufactured sand from certain other rock types has been found to be too dirty or having low magnesium soundness test results. In some areas shale 'popouts' in concrete have occurred but it is felt that this is mainly a surface problem and careful attention to the protection and curing of exposed concrete surfaces may help to alleviate this problem (Emery and Drysdale, 1976).

Detailed descriptions of each of the rock types in the Niagara Region, their engineering properties, as well as their past suitability for various types of aggregate products is included in Appendix VII.

4.8 Potentials Relevant to the Niagara Situation

Reserves of limestone and dolostone within presently licenced areas are estimated to be approximately 230 - 270 million tonnes which is more than enough to satisfy the demand for all aggregate products (strictly from a quantity standpoint) well beyond the year 2000. Many of the current quarries may be able to expand their operations somewhat while others are restricted due to encroaching urbanization or the close proximity of the Niagara Escarpment. Expansion of current operations may bring some additional reserves but the future of the crushed stone industry within Niagara lies in the large undeveloped areas which still occur within the Region. Resources of limestone and dolostone of suitable quality (selected resources) outside of currently licenced areas, urban area boundaries and the Niagara Escarpment Developement Control Area are quite large and estimated to be approximately 6.1 billion tonnes (see Section 4.5).

Underground limestone mining of the Lockport Formation may be possible in the Niagara Region as well, although such a scheme could not economically compete with crushed stone products quarried in the usual manner, at least for the foreseeable future.

4.9 Fine Aggregates Products From Quarries

It has been found that coarse aggregates from quarries are generally acceptable and often superior to natural gravel due to the nature of the crushed stone particles. The shape and angularity of these particles increases the strength of Portland cement concrete and the strength and load carrying capability of granular base and subbase.

Although the shape and angularity of crushed stone from quarries is beneficial for coarse aggregates, this is not generally the case for finer aggregates such as screenings or manufactured sand. Much of the behaviour of Portland cement concrete and other aggregate products is dependent on the finer aggregate fraction. Screenings and manufactured sand have both advantages and disadvantages which will be treated in greater detail in the following sections.

4.9.1 Advantages of Fine Aggregates From Quarries

Fine aggregates from crushed stone operations have been used in asphalt, concrete construction, concrete blocks and masonry mortar. When used in Portland cement concrete, this material has a number of advantages over natural sand (NCSA, 1980) including:

1) Fewer voids in the mix - leading to higher strength concrete

2) Uniform mineralogy and particle shape - A product can be produced which has a more constant mineralogy and particle shape than a similar product produced using only pit sand. This is because pit sand has inherent variabilities of composition and degree of roundness.

3) Comparable Strength - The strength of Portland cement concrete can sometimes actually increase over a comparable mix made with natural sand (Valkirs, MTC-Kingston)

Asphaltic concrete mixes produced from all-crushed stone aggregate have been found to have superior performance than those using natural aggregates. This is due ..."primarily to the ability of angular, rough textured crushed stone aggregates to develop high strength and resistance to shear deformation through aggregate interlock and inter-particle friction (NCSA, 1981)..."

When used in apshaltic concrete, fine aggregates from crushed stone have been found to have higher Marshall stability, they are less affected by initial compaction and increased temperature and offer considerably greater resistence to permanent deformation after repeated loading than identically-graded mixes containing uncrushed sand (Nicholls and Kalcheff, 1979). In addition, fine crushed stone aggregate for asphaltic concrete normally does not require fines removal (Motz, 1974). However, asphalt sand (blend sand) must be added to avoid harsh mixes (Emery, Personal Communication).

Stone screenings are used extensively with coarse aggregate in roadbase and subbase mixes because this combination produces a lower-cost construction material. However, a maximum of 14 percent passing the 75um sieve is accepted by MTC because greater quantities may cause the material to be moisture susceptible (Emery, Personal Communication).

4.9.2 Disadvantages of Fine Aggregates From Quarries

There are also a number of disadvantages of using fine aggregates from crushed stone.

4.9.2.1 Problems Using Fine Aggregates From Quarries in Portland Cement Concrete

Concrete sand is a very high grade product and it has very strict quality requirements. A number of problems have been found when manufactured sand or screenings have been used in Portland Cement concrete including:

1) Gradational Problems

Screenings

The crusher product, when screened through a #4 sieve, will invariably prove to be deficient in the percentages passing the #16, #30 and #50 sieves. Therefore, the product normally referred to as minus #4 screenings cannot be used to replace concrete and unless extensive blending procedures are carried out (Motz,1974).

Manufactured Sand

Specifications for fine concrete aggregate from crushed rock (or manufactured sand) require that 2-10 percent of fines pass the 150 um (no. 100) sieve and 0-5 percent pass the 75 um (no. 200) sieve (see Appendix II). In order to maintain the specification passing the 150 um (# 100) sieve, fines removal of 2 to 3 percent or as high as 20 percent may be required depending on the raw material and type of crushing equipment used (Motz, 1974). Therefore, in order to meet the gradational specifications for manufactured sand, a substantial wastage of material is often required.

2) Decreased Workability

Most crushing operations produce flat or elongated particles which are not usually deleterious in themselves (although they can be), but they signficantly decrease concrete workability (Mollard, Personal Communication). Slump, pumpability (Gray, 1962b) and compactability (Mollard, Personal Communication) is decreased and the difficulty of getting smooth concrete surfaces increases because of increased friction between particles.

Pumpability can sometimes be made more acceptable by using both crushed stone and stone sand if more cement is added or the fine aggregate is graded to have the same blend as a mixture with 80 percent stone sand and 20 percent masonry sand (Gray, 1982b).

General workability can also be improved when air entrainment is used even if relatively poor particle shape is involved (Kalcheff, 1977). Pumpability, as well as some of the other workability problems may also be controlled with the use of additives such as pozzolans.

c) Increased Cement Requirements

Rough, angular particles produced by crushing have greater surface areas than rounded particles of natural sands. This causes increased demand for both cement and water (Rogers, Personal Communication).

d) Higher Production Costs

A survey of opinions (manufacturers, quarry owners, Niagara Sand and Gravel Study (Regional Niagara, 1981)) found that it was generally agreed that producing manufactured sand to the gradational requirements set out in Appendix II would cost between $1.00 to $2.00 more per tonne than to produce a concrete sand to similar specifications. One opinion was slightly lower than this range and it was therefore assumed for this analysis that it would cost approximately $1.30 more per tonne to produce an acceptable manufactured sand over an equivalent concrete sand.

Through a study of available literature and conversations with academics and various people in the industry, it was found that the additional cement required to produce a mix of identical water / cement ratio would cost an average about $2.20 more per tonne of ready-mix. Air-entrainment or the addition of an additive such as a pozzolan to increase workability would add a minimum of $0.50 per tonne increasing the overall price for a tonne of ready-mix to about $4.00.

4.9.2.2 Reduced Pavement Life

If the coarse and fine fractions in pavements come from different sources, they wear at different rates and provide good skid resistence (Rogers, Personal Communication; Regional Niagara, 1981). Pavement life is therefore reduced when both the coarse and fine aggregates come from the same source (Regional Niagara, 1981). Hence, the MTC restricts the use of coarse and fine aggregates from the same quarry (Katona, Personal Communication) for HL1, dense friction coarse and open friction coarse uses (Emery, Personal Communication).

Other substitutes for Fonthill Kame asphalt sand such as dredged sand or recycled foundry sand could potentially replace fine quarried aggregates in pavements.

4.9.2.3 Problems Using Manufactured Sand for Ice Control

Problems have been reported, on occasion, when using winter sand made from crushed stone including 'caking' (Regional Niagara, 1981) and mud formation. For example, during 1976 in the Town of Grimsby, a red mud was left on the streets after having used winter sand made from limestone. The increased costs of cleaning the streets during the spring caused the Town to shun the use of such material again.

Although, MTC currently mixes both natural and manufactured sand for winter sand, they indicated that there is no real problem in making winter sand totally out of quarried material providing it is double-washed to limit fines to less than 5 percent (Rogers, 1979). In fact, MTC recommends the use of this material in the Niagara area to preserve the Fonthill Kame for more important uses (Rogers, Personal Communication).

4.9.3 State-of-the-Art Technology

As the supply of sand and gravel becomes depleted in Ontario, many of the products currently being produced from these materials will slowly become replaced by crushed stone and manufactured sand. This is already the case in the Niagara Region where quarries are currently the major supplier of aggregates (see Section 4.1). Research and demonstration has shown that many perfectly acceptable products can be made from crushed stone and manufactured sand. Research is still going on in this area and currently unacceptable products can become acceptable in the future with proper processing or additives.

Some of the particle shape and gradational problems referred to in Section 4.8.2 have been partially alleviated by recent advances in crushing technology.

One such advancement has been in the development of the Gyradisc crusher. In this system, a fine product is produced by a combination of impact and attrition of a multi-layered mass of particles. Cubical particles are produced but fines must be removed and a series of blending procedures carried out to produce a gradationally acceptable product. The Gyradisc is most suitable for fine aggregate and sand production from highly abrasive stone due to the relatively low metal and power costs in comparison with other types (Motz, 1974).

A new type of crusher developed by Hazemag uses the 'Andreas system' which is based on the principal of reduction by impact. All Andreas type crushers are equipped with two gravity-hung impact aprons which are suspended in the impactor housing. Feed material entering the impactor is caught by the rotor and is then hurled against these impactor aprons and collides with new feed entering the crusher chamber (Hazemag, 1981).

Reduction by impaction occurs along the natural weaknesses and lines of cleavage present in the feed material. Consequently, the material is largely cubical and free from tension cracks. The constant quality of this product is an advantage to many industries, particularly those making granular base products. Concrete produced using this system is said to be smoother and will not break down very easily (Hazemag, 1981).

No quarries are known to be presently producing manufactured sand in the Niagara Region, although it is being produced in other areas of Ontario as well as in the U.S. and overseas. Spratt Sand and Gravel near Ottawa is using the Andreas system to produce a concrete sand for the manufacture of concrete blocks and Miron in Quebec is using a similar system to produce a manufactured sand for use in ready-mix concrete.

4.9.4 Crushed Stone Aggregates for Concrete

It has been found to be technically feasible to produce Portland cement concrete of suitable strength using only quarry products as long as fines removal or blending procedures are carried out and either air entrainment or the addition of certain additives such as a pozzolan are included to enhance workability. Portland cement concrete made with close to 100 percent crushed stone products is being used in South Africa, Australia and in at least one area of the United States (Eastern Tennesee) where there are limited options available.

However, as far as is known, there is no precedent for the complete replacement of concrete sand with manufactured sand in Portland cement concrete anywhere in Central Canada although partial replacement in ready-mix and its use in bricks and blocks does occur. The study by the Regional Municipality of Niagara (Regional Niagara, 1981) found that about 50 percent of the fine aggregates used by concrete block manufacturers but only 8 percent of the fine aggregates used by ready-mix companies was quarried fine aggregates. Most producers feel that the additional production and additive costs (or 'workability costs' in the absence of an additive) which are currently about $4.00 per tonne (Section 4.9.2.1) make it economically unattractive to produce a suitable Portland cement concrete totally from crushed stone. They feel that it is more attractive to blend natural sand with manufactured sand even if this means importation of concrete sand into the Region (Rogers, Personal Communication) from some of the areas discussed in Chapter 6. Importation of concrete sand from the Brantford/Paris area would cost about $2.70 more per tonne than concrete sand from the Fonthill Kame.

Quarries presently supply about 20 percent of the fine aggregates used in concrete products produced in the Region. Interviews with various producers and users of concrete products indicates that there is no real problem with 30 to 40 percent replacement of concrete sand with manufactured sand (60 percent may be acceptable under some circumstances such as for mass concrete) without extensive processing. It is assumed that the quantity of crushed stone in concrete fine aggregates will continue to increase from present levels to a maximum of 30 percent by the year 2,000. It should be pointed out that the Ontario Ministry of Transportation and Communications as a major user of ready-mix concrete presently requires that natural sand must be blended with fine aggregates from quarries to produce an acceptable product and as far as is known it does not presently recognize any quarry in the Central Region as a designated source to supply 100 percent of the fine aggregates used in Portland cement concrete. This may be understandable when one considers how plentiful sand and gravel is, generally, throughout Southern Ontario.

5.0 LAND-BASED SOURCES OF SAND AND GRAVEL IN NIAGARA: AN INVENTORY

5.1 Introduction

All known land-based sources of supply of sand and gravel in the Niagara Region, including both licenced and unlicensed sources, are identified in this Chapter. Some assessment is provided of both the range of possible products that may be made, as well as the constraints to the development of these sources. An important objective was to "flag" any possible resource areas that may contain concrete sand which is now produced primarily on the Fonthill Kame.

The important message that came from this review was that the Fonthill Kame continues to stand out as the most important land-based source of sand and gravel in the Niagara Region. It contains the coarsest and thickest deposits found in both licensed and unlicensed sources. As a result, it is capable of yielding a wide range of coarse and fine aggregate products, the most important one being concrete sand.

Several other resource areas scattered throughout the Niagara Region are capable of supplying a limited range of road-building and construction aggregates including some possible concrete sand. However, given the size of the deposits, their location, and some quality limitations, their develpment on a commercial-use basis seems unlikely.

Except for the Fonthill Kame, the Ministry of Natural Resources believes that Niagara's other land-based sand and gravel deposits, if needed, likely will be used for small wayside pit operations for local road and construction use.

5.2 Background

The main source of information on land-based sources of sand and gravel is the Ministry of Natural Resources. As part of the Aggregate Resources Inventory Program (ARIP), the Ministry has been conducting an inventory and evaluation of all of the aggregate resources (i.e. sand, gravel and crushed stone) found in Niagara, as well as elsewhere in Ontario. The main purpose for the preparation of the ARIP reports in the Ministry's view was:

> "to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans (OGS, 1980a)."

The first ARIP report that was completed in the Niagara Region was for the Town of Pelham. Other reports for the remaining municipalities in the Niagara Region are in the preliminary stages of preparation and likely will be published over the next few years.

In addition to using both the final and preliminary ARIP reports, some unpublished Ministry of Natural Resources' maps and field notes which were prepared during the 1960's and 1970's were also used in the preparation of this Section. The more recent ARIP reports of the Ministry delete reference to reserves within established municipal urban area boundaries. Therefore, the older unpublished data are useful in assessing the potential for extracting sand and gravel within those portions of urban areas which may still be undeveloped and removed from existing urban development. In terms of efficient use of our non-renewable natural resources, a case can be made that extraction of sand and gravel should occur in an area prior to allowing urban development.

The overall distribution of the identified sand and gravel resource areas in the Niagara Region is illustrated on Drawing No. 2 found in the back pocket of this Report. Individual deposit boundaries were derived from various maps provided by the Ministry of Natural Resources. Some of the main sources that the Ministry used to identify these resource areas include:

- Ontario Geological Survey assessment maps
- Quaternary geology maps
- Borehole samples
- Analysis of road and pit cuts
- Aerial photographs and topographical maps
- Water well record analyses
- Field examinations

It is emphasized that the Ministry's information as presented in this Chapter is of a preliminary nature only. The one exception is information pertaining to the Town of Pelham which has been published. Furthermore, the boundaries of the possible resource areas may not be precise. Enquiries regarding individual resource areas should be directed to the District Office of the Ministry of Natural Resources in Fonthill. In many cases, further field checking, drilling and laboratory analyses may be required to more clearly identify the quality, quantity and potential uses of the identified sand and gravel resources.

The Ministry of Natural Resources has done some initial analyses of these deposits. The sand and gravel resource areas that are illustrated on Drawing No. 2 have been assessed according to the quality and quantity of the aggregates that may be contained in the deposits, and their availability for extraction. With the assistance of the Ministry of Natural Resources, each deposit is rated according to its level of importance on an overall "Regional basis". One of three classification levels is assigned to each deposit:

- Primary significance
- Secondary significance
- Tertiary significance

Deposits of "primary significance" are considered to represent large and/or high quality resources in an area. They contain more than 35 percent crushable material, are more than 6 m thick, and do not contain significant quality limitations. Such areas are capable of yielding a wide range of products and could sustain some level of commercial extractive activity. The Fonthill Kame is considered to be of "primary significance" when considering the criteria of quality and quantity noted above. This is supported by the fact that a considerable amount of extraction has occurred here in the past.

Deposits of "secondary significance" are much finer in terms of grain size, are relatively small in size, and are shallow in depth. They have some quality limitations which translate into additional costs to process the material. The range of products that may be made is quite narrow. Such areas are considered suitable only for wayside pit operations.

Deposits of "tertiary significance" are normally poor in terms of quality of the material, they may be fine-grained in nature, or may be very heavily constrained by factors such as existing urban development. In the northern portion of the Niagara Region, for example, there are major constraints to the development of these tertiary resources even if there is higher quality material present. The constraints include urban development, and more importantly, unique agricultural lands which are actively being farmed for tender fruit. Some of these deposits may be useful for local road needs but, are unlikely to support commercial extractions.

It is the opinion of the Ministry of Natural Resources that areas, particularly of "primary significance", should be protected in some way for future extraction. The Ministry notes in its ARIP reports, for example, that these resource areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the municipal official plan. This should occur through consultation and negotiation with municipalities.

5.3 The Fonthill Kame

5.3.1 Geology and Material Suitability

The largest deposit of sand and gravel in the Niagara Region was formed during the retreat of the Ontario - Erie ice lobe which covered the Niagara Peninsula approximately 12,000 to 13,000 years before present (BP). During this time, the ice margin was relatively stationary at the Niagara escarpment and meltwater from the glacier poured off the ice to form a series of glacial lakes. This meltwater deposited stratified sand and gravel in a mound called the 'Fonthill Kame' which rises 40 to 76 metres above the surrounding lake plain (OGS,1980a). As illustrated in Figure 5.1, several deltaic layers form the internal structure of the Kame. It is the upper, coarser deltaic unit and beach deposits which contains the better commercial deposits of extractable sand and gravel aggregate. Since these thicker materials are located generally along the northerly ice-contact portion, extractive activity has tended to be in these locations.

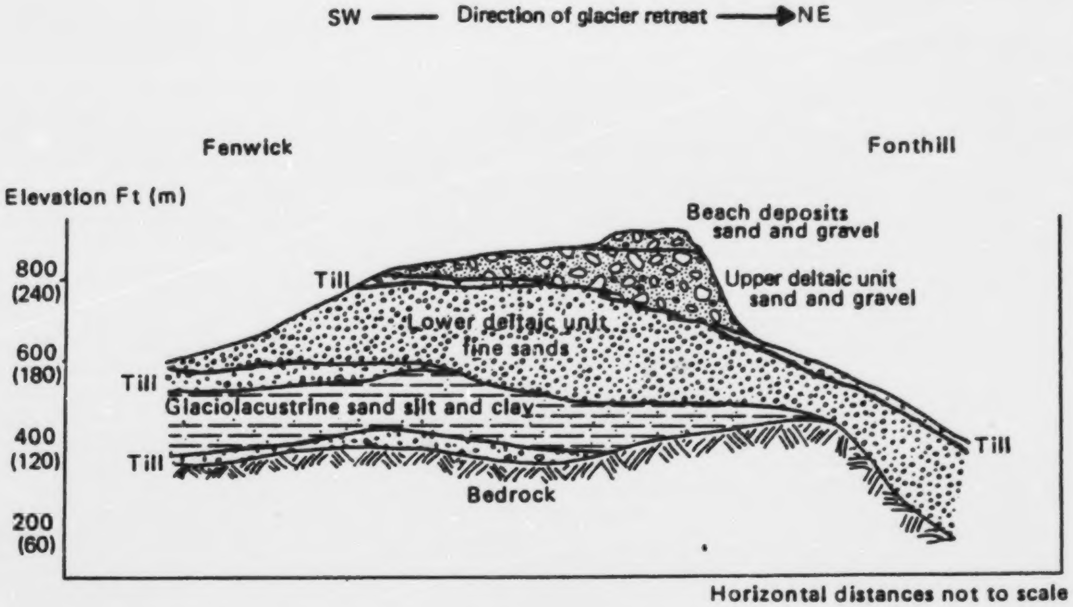

SW — Direction of glacier retreat → NE
Fenwick
Fonthill
Elevation Ft (m)
800 (240)
600 (180)
400 (120)
200 (60)
Beach deposits sand and gravel
Upper deltaic unit sand and gravel
Till
Lower deltaic unit fine sands
Till
Glaciolacustrine sand silt and clay
Till
Bedrock
Till
Horizontal distances not to scale

Figure 5.1 - Generalized Internal Structure of the Fonthill Kame (southwest ridge). After Feenstra, unpublished.

Although the Kame is the predominant source of natural aggregates in the Region, its sands are generally inferior to most sand deposits found elsewhere in Southern Ontario (Deike, 1978b). It is to be noted here, that at one time, the Fonthill Kame deposit did not meet Ontario Ministry of Transportation and Communications (MTC) specifications for concrete sand.

The Kame materials predominantly consist of weathered sandstone (from the Whirlpool and Thorold Formations), red shale (from the Queenston Formation), siltstone and conglomerate. Limestone and granite dominate the coarser sand sizes while quartz is the most common mineral in the fine sand fractions (Deike, 1978b).

The sand in the Kame is red in colour due to the presence of hematite in shale subsequently decomposed into a clay which now coats the sand particles. Successful methods of removing these clay coatings have been developed and the sands obtained through the beneficiation processes of washing and jigging are suitable for most concrete work and asphalitic mixes. Blending of the sands with quarry screenings is sometimes required for certain hot-laid mix designs. (Deike, 1978b).

The Kame may be sub-divided into three general areas of "primary significance", on the basis of topography, geology and on the distribution and suitability of the various aggregate units of which it is composed (OGS, 1982e):

1) The Upper Terrace
2) The Main Terrace
3) The Northwest-Trending Ridge

These areas are shown in Figure 5.2.

5.3.1.1 The Upper Terrace

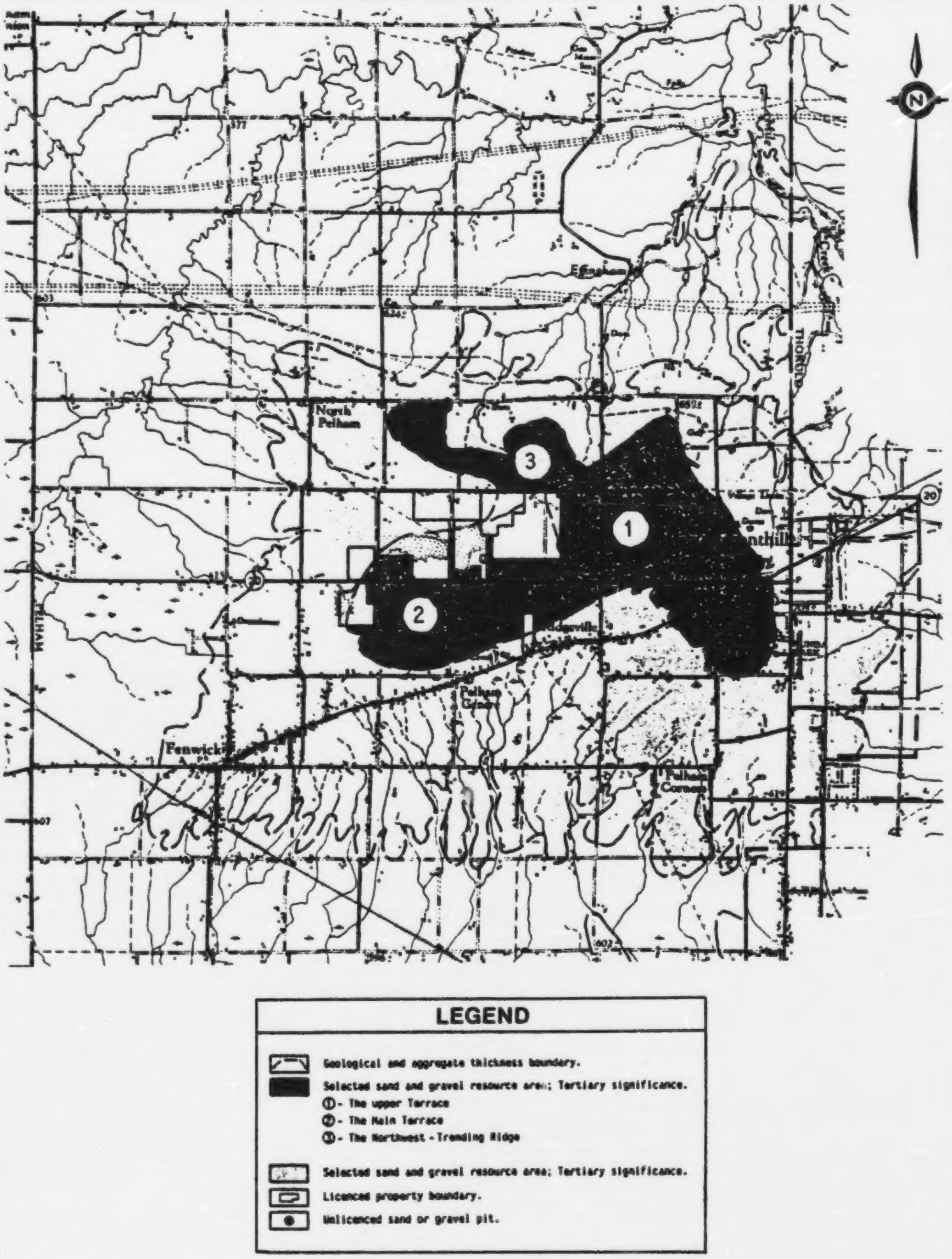
The upper terrace is located to the north of Highway 20 and flanks Effingham Street. This area contains the coarsest-grained sediments which remain in the Kame.

The upper 9 to 17m of this material may be suitable for a wide range of fine aggregate products including apshalt and concrete sand (if excess fines are removed by screening and washing) and some sections of material are also suitable for Granular"B"and"C"(OGS, 1982e).

Approximately 109 hectares containing 37 million tonnes of presently unlicenced reserves are available for extraction in the upper terrace (OGS, 1980a).

5.3.1.2 Main Terrace

In the past, virtually all of the aggregates extracted from the Fonthill Kame have come from the northern margin of the main terrace which makes up most of the


N
North Pelham
Effingham
Fonthill
Ridgeville
Pelham Centre
Fenwick
Pelham Corners
THOROLD
PELHAM
20
1
2
3
LEGEND
Geological and aggregate thickness boundary.
Selected sand and gravel resource area; Tertiary significance.
① - The upper Terrace
② - The Main Terrace
③ - The Northwest - Trending Ridge
Selected sand and gravel resource area; Tertiary significance.
Licenced property boundary.
Unlicenced sand or gravel pit.

The Fonthill Kame Resource Area

Figure 5.2

deposit (OGS, 1982e). Both Telephone City Gravel Materials Limited (or TCG) and Steed and Evans Limited (the two companies presently operating on the Kame) started their operations in the sands and gravels in the upper deltaic unit along the northern ice-contact face of the Kame exposed here.

The higher quality aggregate is restricted to the upper 10 to 12 m near Highway 20 to 6 m (or less) and 3 m at the southern and western edges of the terrace respectively. Use of the material at greater depths for fine aggregates may require additional processing. Although the material in the main terrace is considerably coarser-grained to the north where it has been heavily extracted, it contains very little gravel-sized material south of Highway 20 where a large proportion of the extractable area lies. Being generally finer-grained, the material in the main terrace is not suitable for as wide a range of aggregate products as the upper terrace material (OGS, 1982e).

Approximately 214 hectares containing 36 million tonnes of presently unlicenced aggregate reserves are available for extraction in the main terrace (OGS, 1980a).

5.3.1.3 The Northwest-Trending Ridge

This area has not been exploited for aggregates in the past and therefore relatively little information regarding the quality of the material is available. A fairly recent investigation (OGS, 1982e) has shown that there may be a considerable thickness of material suitable for a variety of aggregate products.

Approximately 117 hectares containing 13 million tonnes of presently unlicenced reserves are estimated in the northwest-trending ridge (OGS, 1980a).

5.3.1.4 Other Deposits in the Town of Pelham

The Ministry of Natural Resources has identified some deposits which lie at the extremities and beyond the Fonthill Kame feature. On an overall Regional basis, these are considered by the Ministry to be resource areas of "tertiary significance" only. These deposits consist of fine-grained lower deltaic sand and silts and associated fine-grained, nearshore lacustrine sediments. One small anchor-shaped deposit, for example, lying a short distance east of the Town of Fonthill, is a relatively young pre-Iroquois beach and bar deposit of stratified sand and gravel about 2 metres thick.

The three licenced pit operations (Steed and Evans Ltd., T.C.G. Materials Ltd. and D.L. Stephens Contracting Niagara Ltd.) are located partially within the tertiary area. In the past, several small abandonned pits south of Canboro Road also supplied some material.

Although approximately 1,429 million tonnes of aggregates of "tertiary significance" reside outside of licenced areas in the Town of Pelham, the Ministry of Natural Resources indicates that these deposits are probably of little commercial value because of the absence of crushable material. The potential uses of these deposits have not yet been determined.

Constraints to development of these deposits may include urban and suburban development, orchards, and recreational areas.

5.3.2 Production From the Fonthill Kame

Although the production from the Fonthill Kame has declined from approximately 1.7 million tonnes in 1972 to 0.47 million tonnes in 1984 (Figure 1.3), it continues to supply approximately 12 percent of the total aggregate production (Figure 1.4) and 80 to 90 percent of all sand and gravel (see Figure 5.3) produced in the Niagara Region.

The three licenced operations occupy about 187.3 Ha, two of which extracted between 2 and 3 times as much sand and gravel as all other presently operating land-based pits and dredging combined in the Region.

5.3.3 Products Currently Being Produced From the Fonthill Kame

The Fonthill Kame presently produces large quantities of certain types of construction aggregates. Figure 5.4 shows the percentage of the total Regional production of each product type produced by the Fonthill Kame. As is evident from this graph, the Kame produces approximately 60 percent of the fine aggregates, 10 - 40 percent of granular base and subbase and generally less than 10 percent of all other aggregate products produced in the Niagara Region.

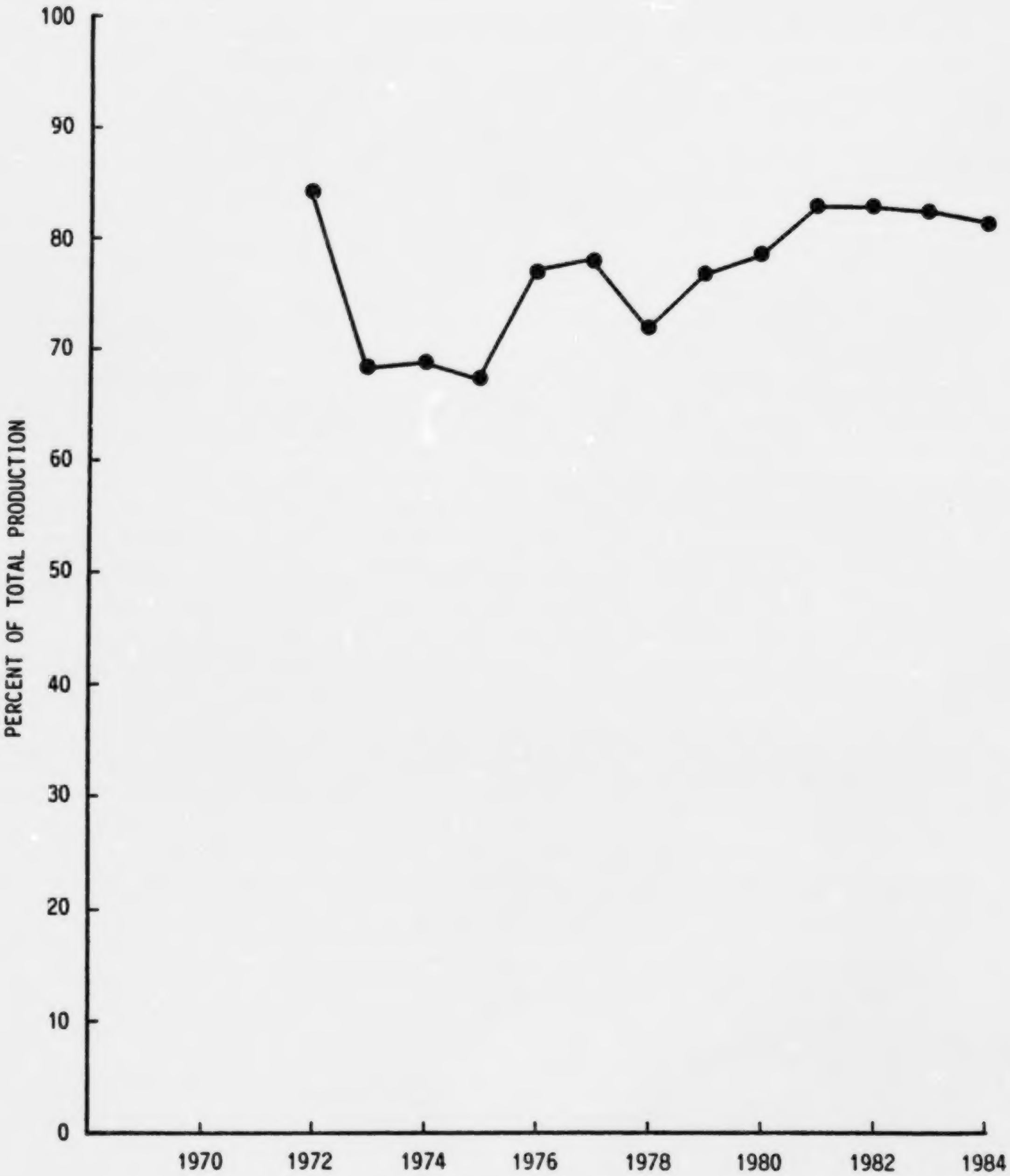
Specific products currently being produced by these operators includes granular "A", "B" and "C" (current designation, MTC granular B, Type II), 3/4" crush and all types of sand products such as concrete sand, asphalt sand, sand cushion, winter sand and sand fill. Approximately 36 percent of the Kame's total production is granular base and subbase, 16 percent is sand cushion and sand fill and 48 percent is fine aggregates including concrete sand, asphalt sand, salted sand, winter sand and mortar sand (see Table 5.1).

The Fonthill Kame is presently the only major supplier of concrete sand (200,000 - 300,000 tonnes per year) and sand cushion and one of the major suppliers of asphalt sand (30,000 to 45,000 tonnes).

5.3.4 Reserves in the Fonthill Kame

A recent survey by the Regional Niagara Planning Staff of the three major licenced pits on the Fonthill Kame indicates that approximately 2 million tonnes of aggregate reserves remain in presently licenced areas. If it is assumed that 60 percent (information obtained from the Regional Niagara Planning Staff) of reserves is suitable for concrete sand, approximately 1.2 million tonnes of concrete sand may be produced from the remaining licenced areas, representing approximately 3 or 4 years of supply.

Although licenced reserves may be small, total unlicenced reserves of primary signficance in the Kame are sufficient to provide many more years of production. An estimate by the Engineering and Terrain Geology Section of the Ontario Geological Survey indicates that approximately 440 hectares containing 86 million



PERCENTAGE OF SAND AND GRAVEL
PRODUCED BY THE FONTHILL KAME

Figure 5.3

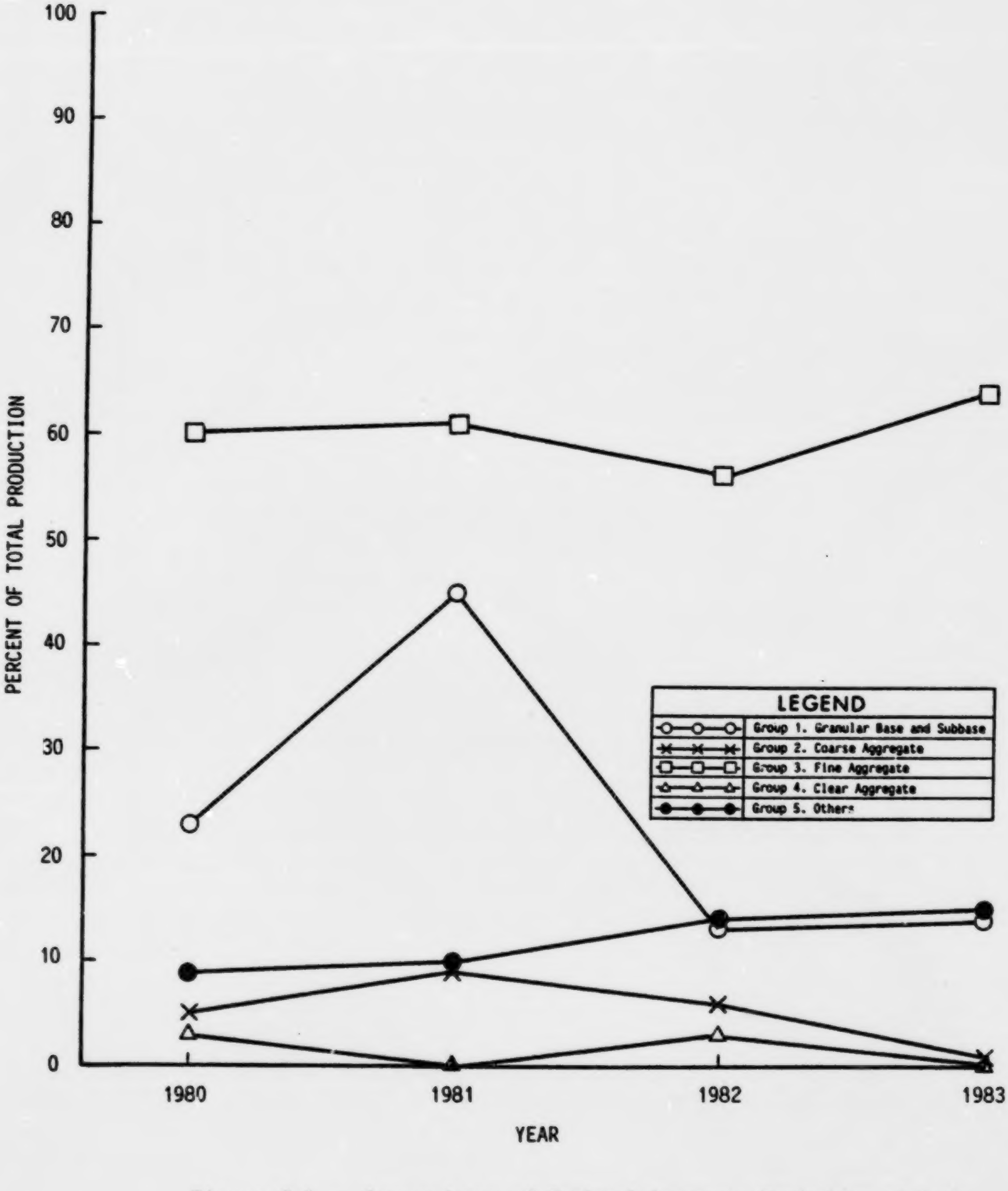


Figure 5.4 - Percentage of Regional Aggregate Production of Each Product Group Satisfied by the Fonthill Kame

Table 5.1

Sand and Gravel Products from the Fonthill Kame

Product	Percentage of Total Production
a) Granular A, Granular B, Granular C (i.e. pit run and 3/4" crush which are granular base and sub-base materials)	36%* (31%**)
b) Sand cushion (type of sand fill)	16%* (10%**)
c) Sand and other fill (backfill material)	
d) Concrete sand (concrete structures and pavement)	48%* (59%**)
e) Asphalt sand (hot-laid asphalt)	
f) Salted sand & winter sand (ice control aggregate)	
g) Mortar sand (masonry purposes)	

Notes: * Average for the years 1981-1983
** Average for the years 1977-1979

Sources: Ministry of Natural Resources, 1984.
Regional Municipality of Niagara Survey of Aggregate Producers, 1980.

tonnes of aggregates of primary signficance (excluding setbacks and cultural constraints) are still available for extraction in the three major areas on the Kame. If again 60 percent of the material is assumed to be suitable for concrete sand production, then 52 million tonnes of concrete sand may be produced from the available resources. This could represent all of the Region's concrete sand requirements for the forseeable future.

Regional Niagara has recently agreed to an expansion by TCG which would provide an additional 6.2 million tonnes of aggregate production. In addition, an expansion of the Steed and Evans property which would provide an additional 1 million tonnes of aggregate production is currently under review.

5.4 Review of Sand and Gravel Resource Areas in the Niagara Region

An inventory of the land-based sources of sand and gravel in the Niagara Region outside of the Fonthill Kame is presented in Appendix VIII. The deposits are described and assessed according to the area in which they are situated. The areas include:

- Grimsby, Lincoln and West Lincoln
- St. Catharines and Niagara-on-the-Lake
- Niagara Falls
- Welland and Thorold
- Wainfleet
- Port Colborne and Fort Erie

Information is presented on such topics as the nature and geological origin of the sand and gravel deposits, estimated supplies of material, existing and potential uses of the material, and any constraints to their future development.

The main highlights, and the conclusions that flow from the above review, are presented below in Section 5.5. Most importantly, some assessment is made about the ability of these other land-based sources to meet the sand and gravel needs now satisfied by the Fonthill Kame, particularly for the production of concrete sand.

5.5 Summary and Conclusions

The Niagara Region contains extensive resources of sand and gravel. The Ministry of Natural Resources estimates that total sand and gravel resources outside of both licensed sources and urban areas may amount to about 2 billion tonnes of material, of which approximately 1.5 billion tonnes is in the Town of Pelham. This is not to say that a wide range of products can be made from all of these deposits. Moreover, due to a variety of constraints present, such as existing development or environmental considerations, and given quality, quantity and economic considerations, this supply is significantly reduced. Table 5.2 shows

Table 5.2

Assessment of Land-Based Sources of Sand and Gravel in Niagara*
(in millions of tonnes)

Area	Total Original Tonnage	Primary Significance	Secondary Significance	Tertiary Significance
1. Grimsby, Lincoln & West Lincoln	129	0	0	129
2. St. Catharines & Niagara-on-the Lake	202	0	0	202
3. Pelham	1,515	36	0	1,429
4. St. David's	14	0	2	12
5. Welland, Thorold and Southwest Niagara Falls	26	0	7	19
6. Wainfleet	28	0	8	20
7. Port Colborne & Fort Erie	118	4	0	114
Total	2,032	90	17	1,925

Note: *Each deposit was ranked according to its level of significance on a "regional basis". These rankings were determined with the assistance of the Ministry of Natural Resources.

that, in fact, only about 5 percent of this supply, or about 107 million tonnes is considered to be important enough by the Ministry to be classified either as "primary" or even "secondary significance". On the other hand, 95 percent of the Regions' resources or about 1.9 billion tonnes is considered to be of "tertiary significance" only. If ever used, this material would mainly be suited only for low specification construction aggregates such as backfill, and possibly in some cases, subbase materials. The glaciolacustrine deposits, north of the Niagara Escarpment for example, are relatively fine-grained and contain objectionable quantities of clay and/or silt fines.

Licenced land-based supplies of sand and gravel are diminishing quite rapidly. A recent survey of local aggregate producers reveals that total licensed land-based reserves of sand and gravel (as of January 1, 1985) stand at about 2.3 to 2.7 million tonnes (telephone survey by the Regional Niagara Planning Department in December, 1984) of which about 2.0 million tonnes are in the Town of Pelham (see Table 5.3). Assuming an average annual production level of 693,000 tonnes from licensed pits for the last five years, this supply theoretically will meet only 3 or 4 more years of Niagara's demand.

Table 5.4 also is included to show the distribution of all sand and gravel production in the Niagara Region in 1979 and 1983. Information regarding those areas outside of the Pelham are described in the sections that follow.

The Town of Pelham (including the Fonthill Kame) continues to stand out as the Region's largest land-based source of selected aggregate resources of "primary" and "tertiary significance". The only other deposits in the Region that are considered by the Ministry of Natural Resources to be of "primary significance" are in Port Colborne and Fort Erie. They are four small deposits of beach and deltaic sand and gravel containing about 3.6 million tonnes of material. This material may be suitable for some road building and construction aggregates including some possible concrete sand. However, the size and depth of the deposits may discourage their development on a commercial-use basis.

Licenced pits in the southern part of the Niagara Region are found within the shoreline dunes which are considered to be of "tertiary significance" only. This is mainly due to their very fine-grained nature and a variety of constraints to their development. The material here is suitable only for a narrow range of low-specification products. In 1983, these pits accounted for less than 1 percent of the Region's total sand and gravel production and very little material is left in reserves (ie. only 27,000 to 36,000 tonnes).

Several deposits in Wainfleet, Welland and Niagara Falls may contain some material which could be produced into concrete sand. However, due to their size, quality considerations and constraints to their use, the Ministry considers these resources to be of "secondary significance" only. Total resources of this type amount to about 17 million tonnes.

The deposits in Wainfleet and Welland are small and are shallow glaciolacustrine deposits of fine sand and gravel. They are capable of supplying some low specification construction aggregates like backfill, granular "B" and granular "C" materials. While granular "A" and concrete sand might be produced if processing

Table 5.3

Estimated Licensed Land-Based Reserves of Sand and Gravel, 1984 (in 000's of tonnes)

Area	Number of Operations	Tonnage	% of Total Supply
Pelham	3	2,000.0	79%
Niagara Falls	4	510.0	20%
Fort Erie & Port Colborne	2	27.0-36.0	1%
Total	9	2,540.0	100%

Source: Regional Niagara Survey of Aggregate Producers, December, 1984.

Table 5.4

Distribution of Sand and Gravel Production, Including Dredging, in Niagara by Area Municipality- 1979 and 1984

Area	Number of Operations	Total Production (in 000's of tonnes) 1979	1984**	% of Total Production 1979	1984
I Land-Based Pits					
Pelham	3	747.0*	468.5	79.0%	81.3%
Niagara Falls	4	71.0*	36.0	7.5%	6.3%
Fort Erie	1	20.4*	-	2.2%	-
Port Colborne	1	8.3*	4.2	0.8%	0.7%
II Dredged Sand					
from Lake Ontario and the Niagara River	1	99.3**	67.3	10.5%	11.7%
Total	10	946.0	576.0	100.0%	100.0%

Sources: *Regional Municipality of Niagara Survey of Aggregate Producers, 1980

**Ministry of Natural Resources, 1981 and 1985 equipment were available, the Ministry believes that the size of deposits may discourage their development on a commercial-use basis.

Finally, the St. David's glaciolacustrine delta deposit in Niagara Falls has very limited potential in terms of its ability to provide a full range of fine aggregates like concrete sand. According to local producers and the Ministry of Natural Resources, the coarser materials have been extracted and only fine sands remain that are suitable mainly for fill. In 1983, pits in St. David's accounted for only 6 percent of the Niagara Region's total sand and gravel production. This figure is slightly down from the 1979 figure of almost 8 percent. It has been estimated that only about 2.7 million tonnes of material remain within licensed and unlicenced areas.

Some coarser materials like granular "C" or some concrete sand might be available in St. David's, however, the locations of the material appear to be scattered and are at great depths. Local producers and the Ministry believe that it is unlikely that the higher quality materials that might be available will ever be extracted, unless more extensive geological testing is carried out. This likely would be the responsibility of private investors.

One of the main objectives of this chapter was to "flag" possible resource areas that may contain concrete sand. It is quite clear that the Fonthill Kame is the largest land-based source of sand and gravel in the Niagara Region. About 86.4 million tonnes of material here are considered to be of "primary significance", much of which is suitable for the production of concrete sand.

Other deposits of "primary" or "secondary significance" in Niagara outside of the Kame do have some limited potential for the production of concrete sand. Total resources in these deposits amount to about 12.7 million tonnes of material. These deposits are found in the following areas:

1) Three small deposits in southeast Welland on or near the Welland/Niagara Falls municipal border (7.3 million tonnes)

2) Five small deposits in Wainfleet near the Port Colborne airfield (1.8 million tonnes)

3) Four small deposits in the central portions of Port Colborne and Fort Erie (3.6 million tonnes)

The Ministry of Natural Resources believes that some low specification construction aggregates like backfill, granular "B" and granular "C" could be produced from these deposits. Furthermore, if processing facilities were available, some granular "A" and concrete sand could also be produced. However, due to the quality constraints of the deposits themselves, all of this material probably could not be processed into concrete sand. The Ministry of Natural Resources estimates that between 50 and 75 percent of the material from these deposits may be used in the production of concrete sand. The proportion may vary from one deposit to another and may only be determined after careful aggregate analysis. If one assumes a standard ratio of 3 to 2 (that is 60% concrete sand to 40% other sand and gravel products), then a little over 7.3 million tonnes of material may be available from twelve scattered deposits to enable production of concrete sand. In comparison, the Fonthill Kame deposit itself may be capable of yielding about 51.8 million tonnes of concrete sand if this same ratio is assumed.

Finally, the future development of these land-based deposits outside of the Fonthill Kame for commercial use, particularly in producing concrete sand, is difficult to predict. One of the factors that certainly could affect the development of these resources would be the availability of sand and gravel from the Fonthill Kame. It is noted, however, that land-based sources in the Niagara Region outside of the Kame alone probably could not satisfy the Region's long term demand for concrete sand.

6.0 IMPORTATION OF MATERIALS

6.1 Introduction

The Niagara Region has been a net exporter of aggregates for a number of years. Slightly over 1.0 million tonnes of crushed stone (dolostone) products have been exported annually from Port Colborne Quarries to locations mostly in Ohio (Peat Marwick and Partners, 1984). In addition, small quantities of sand and gravel aggregates have been exported from dredging operations as well as from the Fonthill Kame (Regional Niagara, 1981).

Imports of sand and gravel into the Region have been substantially smaller than exports in the past, although they are still quite large. The vast proportion (approximately 98 percent) of the 130,000 tonnes / year (Regional Niagara, 1981; Peat Marwick and Partners, 1984) imported represents foundry sand imported by General Motors from Michigan. Small amounts have also been imported from land-based pits in the Brantford/Cambridge area and Haldimand/Norfolk since sources of high quality sand and gravel are scarce and regional disparities force some users in the western part of the Region to import.

The Fonthill Kame presently supplies approximately 14 % (or 575,000 tonnes) of the total aggregates produced in the Niagara Region.

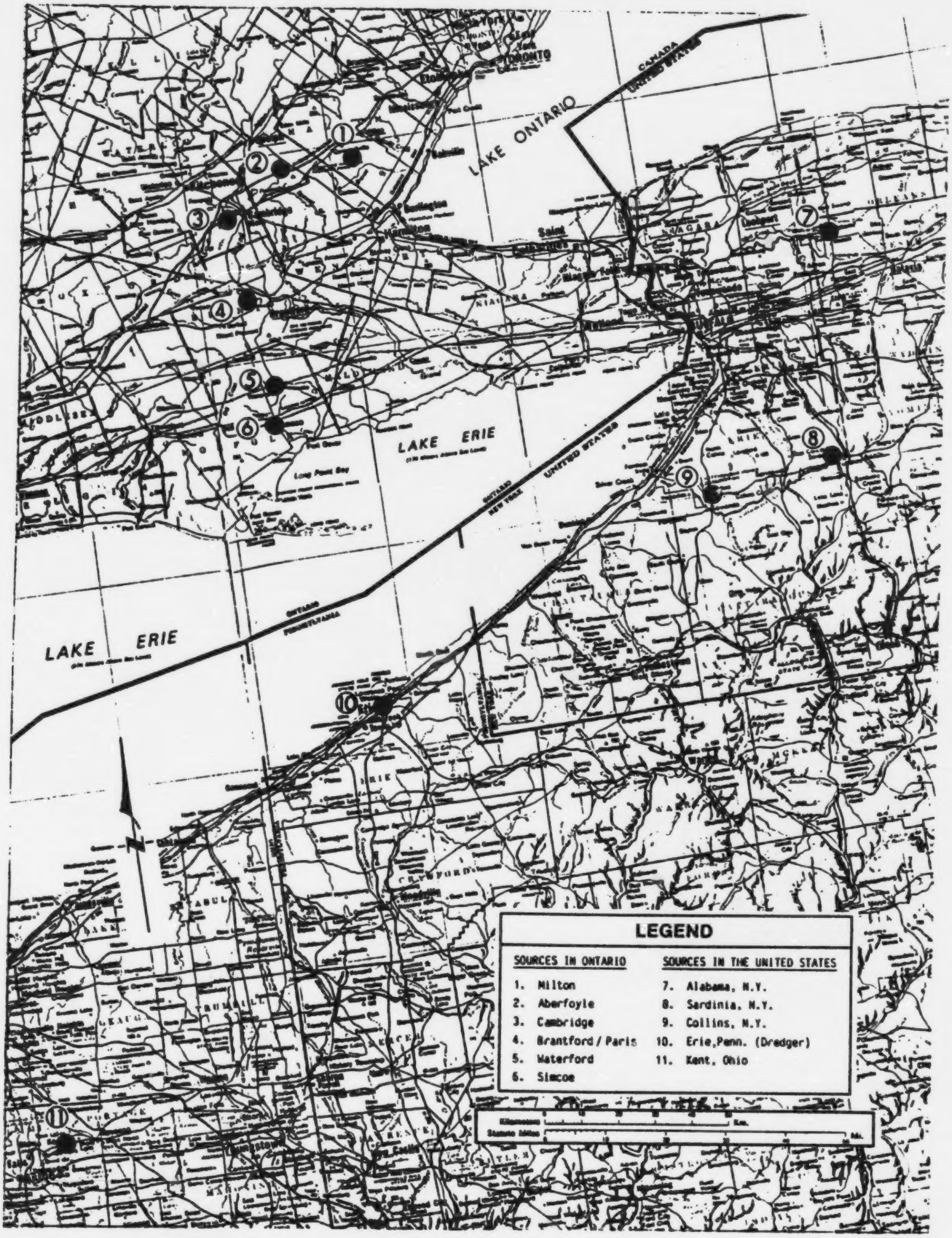
The supply/demand picture must be considered on a product-by-product basis. It is found that the Kame presently provides 80 percent of the sand and gravel, 60 percent of the fine aggregates and 84 percent of the concrete sand produced in the Region. If the Kame can no longer supply sand and gravel to the Region and other alternatives cannot fully satisfy the range of products needed, then the situation would change and the Region would become a net importer of certain high grade products such as concrete sand.

6.2 Potential Sources of Natural Aggregates Outside of the Niagara Region

There are a number of potential sources of aggregates outside of the Niagara Region which could replace the sand and gravel products currently being supplied by the Fonthill Kame. Although there are some closer sources, only those which could supply the quantity and quality of sand and gravel which would be required by the Region are considered. In addition, only those sources which have traditionally supplied concrete sand in particular were included since this commodity would be in short supply if the Kame was no longer operating.

Several key sources in both Ontario and bordering U.S. states were identified that could satisfy the demand for fine aggregates and concrete sand in particular (see Figure 6.1).

The first priority was to satisfy the needs of the Niagara Region from sources inside Ontario. Six potential areas were identified using information obtained


LAKE ONTARIO
CANADA
UNITED STATES
LAKE ERIE
ONTARIO
NEW YORK
PENNSYLVANIA
①
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③
④
⑤
⑥
⑦
⑧
⑨
⑩
⑪
N
LEGEND
SOURCES IN ONTARIO
1. Milton
2. Aberfoyle
3. Cambridge
4. Brantford / Paris
5. Waterford
6. Simcoe
SOURCES IN THE UNITED STATES
7. Alabama, N.Y.
8. Sardinia, N.Y.
9. Collins, N.Y.
10. Erie,Penn. (Dredger)
11. Kent, Ohio
Kilometres
Km.
Statute Miles
Mi.

Figure 6.1 - Possible Outside Sources of Concrete Sand Near the Niagara Region

from the Ministry of Natural Resources. These include:

1) Milton
2) Aberfoyle
3) Cambridge
4) Brantford/Paris
5) Waterford
6) Simcoe

The first four are by far the most important. Waterford and Simcoe were only considered because of their relatively close proximity to the Region and the fact that they have produced concrete sand at one time in the past or could conceivably produce minor amounts of this material in the future. In addition, these two sources were identified by representatives of the Ontario Ministries of Transportation and Communications (Southwestern Region) and Natural Resources as possible future sources of concrete sand.

The quality and quantity of aggregates available at each of the sources identified in Ontario will be dealt with in greater detail in Section 6.3.

The remaining sources of concrete sand are shown on Figure 6.1 are all in the United States and were identified through telephone conversations with representatives of the various Geological Surveys and Departments of Transportation in the bordering States of concern. These possible sources include:

7) Alabama, New York
8) Sardinia, New York
9) Collins, New York
10) Erie, Pennsylvania
11) Kent, Ohio

Although land-based sources of sand and gravel do occur in the northern part of Pennsylvania, they are generally of little consequence and (10) refers to the dredging operation currently taking place in Lake Erie. This source has been discussed in much greater detail in Chapter 3 on Dredging.

The other American sources have been identified by officials as past (or future) major producers of concrete sand. The quality and quantity of aggregates at these sources will not be dealt with in this Study in any greater detail, although the feasibility of transportation to the Niagara Region will be mentioned in Section 6.4.

6.3 Potential Sources Within Ontario

The major potential Ontario sources of supply of sand and gravel to the Region are shown in Figure 6.2. These areas represent most of the primary selected sand and gravel resource areas identified in the Ontario Geological Survey Aggregate Resource Inventory Papers which are within reasonable distance to the Niagara

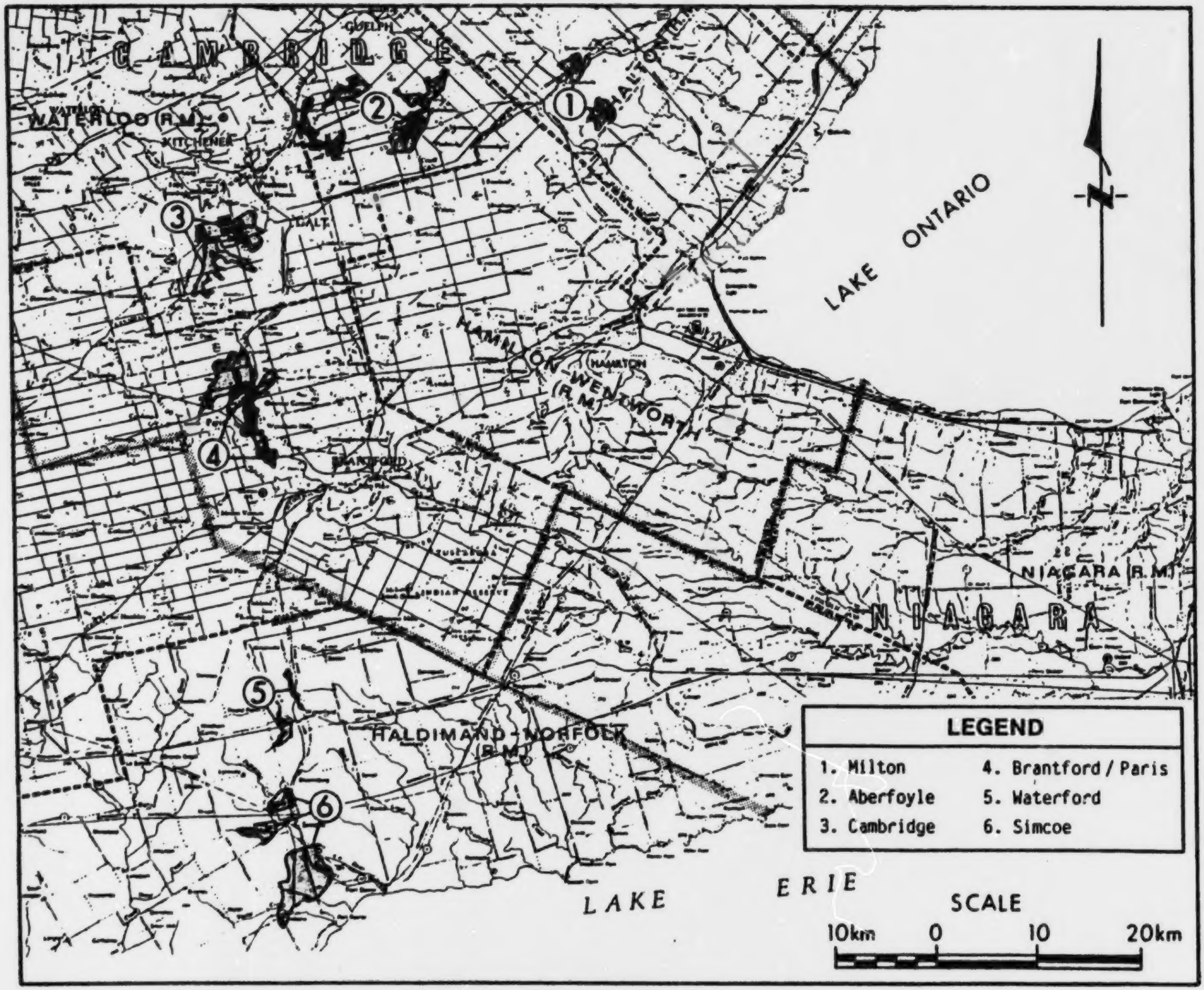

CAMBRIDGE
GUELPH
WATERLOO (R.M.)
KITCHENER
GALT
HALTON
HAMILTON-WENTWORTH (R.M.)
HAMILTON
BRANTFORD
HALDIMAND-NORFOLK (R.M.)
NIAGARA (R.M.)
NIAGARA
LAKE ONTARIO
LAKE ERIE
N
①
②
③
④
⑤
⑥
LEGEND
1. Milton
2. Aberfoyle
3. Cambridge
4. Brantford / Paris
5. Waterford
6. Simcoe
SCALE
10km
0
10
20km

Figure 6.2 - Possible Ontario Sources of Concrete Sand
Near the Niagara Region
(Deposits in light shading, licenced areas in black)

Region. Although other deposits within the six areas mentioned may also have been included, they have either not been identified as possible suppliers of concrete sand in the Resource Inventory Papers themselves or they have not been traditional suppliers to the Ontario Ministry of Transportation and Communications. Therefore, the areas shown represent highest selected resources available which may be suitable for concrete sand production within reasonable distance to the Niagara Region. The darkened areas shown represent currently licensed pits. Each of these sources is described in detail in the following subsections.

The reserve estimates given for each of these areas are based on published information in the Ontario Geological Survey Aggregate Resource Inventory Papers. Since these estimates are, in some cases, up to 5 or more years out of date, they are meant only as a guide. Quantity and quality determinations of the suitability of these deposits as a source of only concrete sand would be required in a more detailed study.

6.3.1 Milton

Two areas have been identified in the vicinity of Milton which could supply concrete sand in sufficient quantities. These areas contain outwash sand and gravel deposited during the advance of the Ontario lobe of glacial ice and represent the thickest portion of the outwash deposit. Although the material is quite good, many of the gravel fragments in two of the licenced properties were found to be coated with loosely cemented 'red fine particles'. Large blocks of coarse gravels cemented by calcium carbonate and large amounts of silt and clay have also been noted in some areas.

Pits in these deposits expose 5 to 14 m of materials suitable for granular "A" and "B", as well as concrete sand and some types of crushed asphaltic gravel (OGS, 1982a).

Another smaller area to the southwest which is part of the same complex may not be suitable for concrete aggregate due to the presence of a high percentage of Queenston shale fragments (OGS, 1982b).

The Ministry of Natural Resources estimates that the two areas mentioned have approximately 289 hectares available for extraction (outside of presently licenced areas and all other cultural constraints) containing sand and gravel resources of 40 million tonnes. Although the total licenced area was about 244 Ha. in the Town of Milton at the time the ARIP report was written (OGS, 1981b). The quantity of available reserves in licenced areas today is not known.

6.3.2 Aberfoyle

Several major deposits of sand and gravel are located near the Town of Aberfoyle in an outwash deposit associated with the Galt Moraine (OGS, 1982c). Some of these areas are currently producing concrete sand.

The largest and most important deposit completely surrounds the town of Aberfoyle. Portions of the deposit have depths of up to 18 m and contain 40 to 70 percent gravel. Since the material in the eastern part of this area was deposited close to the glacial ice front, the sand and gravel is less well-sorted. In the western part, the material becomes thicker and finer (OGS,1982c).

This material is suitable for concrete and hot-mix applications as well as for road base. Granular "A", "B" and "C" can be produced but MTC has suggested that the sand contains too many fines for HL4 applications. The material therefore requires blending for hot-mix applications (OGS, 1982c). At least one pit is approved by MTC for the production of concrete sand.

Two smaller outwash deposits are located to the west of the main one. The one to the extreme west is divided into two parts. The northern half is suitable for granular "A" and "C" although blending of different grade sands is required in some areas to produce an acceptable hot-laid mix. The southern half of this deposit is part of the outwash plain and spillway deposit of the Paris Moraine. This material is suitable for granular base course "A" and 16 mm crushed stone types "A" and "B". The stone portion is acceptable for hot-laid mix no.'s 3,4,5,6 and 8. The sand portion meets the specification for all grades of hot-laid asphalt as well as concrete sand (OGS, 1982c). Since there is a high percentage of silt, blending will be necessary for all hot-laid mixes (Deike, 1978a).

The most northerly deposit in this area is an outwash deposit containing fine material marginally suitable for crushing into granular "A". With processing, some parts of the deposit would also be suitable for concrete and asphalt sand (OGS, 1982c).

Estimates by the Ministry of Natural Resources (OGS, 1982c) indicate that approximately 2125 presently unlicenced hectares are available for extraction in these three main areas having resources of 281 million tonnes (from OGS, 1982c). Although the total licenced area was about 672 Ha. in Puslinch Township (OGS, 1982c), reserves remaining in these areas are presently unknown.

6.3.3 Cambridge

The deposits in the Cambridge area are a series of outwash terraces which were deposited near a melting glacial ice margin (OGS, 1980b).

The main deposit and the only one which might be considered suitable for large deposits of concrete sand is shown in Figure 6.2. It consists of 8 to 9 metres of poorly to moderately sorted gravels with 33 percent stone content, overlying considerably finer-grained material which has little potential for crushing (OGS, 1980b).

Quality data from MTC indicates that this material is suitable for a wide range of coarse aggregate products including concrete aggregate, although some selection and sand control may be required in certain areas. Several pits in this deposit have traditionally supplied concrete fine aggregate (OGS, 1980b).

This area is well suited for extractive development since the potential for rail haulage exists along the Canadian Pacific Railway which runs along the southern portion of the deposit.

Another major area south of the main deposit also exists. Pits in the area expose moderately sorted and stratified sand and sandy gravel. The distribution of crushable gravel is variable, but field investigation indicates that it may be as much as 40 to 50 percent in some areas. As in the main deposit, the gravel in this area overlies considerably sandier material (OGS, 1980b).

MTC has given this area a low to moderate rating due to the excess of fines and clay coatings on gravel particles. However, at least one pit from this deposit has been approved for concrete sand and therefore this area is also included in the reserve estimates.

The Ministry of Natural Resources (OGS, 1980b) has estimated that the quantity of reserves in all licenced areas in the Township of North Dumfries (which includes the areas mentioned above) to be about 64 million tonnes. If it is assumed that the annual rate of production from these pits is about 840,000 tonnes and the areas licenced have not changed significantly, then presently licenced reserves of sand and gravel are about 60 million tonnes.

Estimates by the Ministry of Natural Resources (OGS, 1980b) indicate that the two deposits mentioned above have an unlicenced area of 1630 hectares (including cultural constraints) containing approximately 180 million tonnes.

6.3.4 Brantford / Paris

The Brantford / Paris area is another major source of selected sand and gravel and probably represents the most feasible source of concrete sand to the Niagara Region. Although several deposits exist here, there are two primary sources of concrete aggregates.

The first is a large generally flat lying, outwash deposit located along the west bank of the Grand River. Pits in this area expose 4.5 to 9 m of good quality material containing approximately 55 percent stone, 35 percent sand and 10 percent silt and clay.

The total depth of the deposit is variable and ranges from 5 to 18 m (OGS, 1980c).

The aggregate is acceptable for the production of surface paving and structural concrete stone of high quality (OGS, 1980c).

This area has 300 hectares currently available for extractive purposes outside of presently licenced areas and contains an estimated 75 million tonnes of aggregates (OGS, 1980c).

Although rail access is generally good, road access is not, since all major truck routes pass through the Town of Paris (OGS, 1980c).

The second area is located on the east side of the Grand River valley, east of the City of Paris and extends south close to the Brantford City Limits. This area forms another part of the Grand River meltwater channel system and has outwash gravel similar to that of the area mentioned above. This area has been a major aggregate source for many years (OGS, 1980d). The northern part of the area contains uniform, horizontally-stratified coarse gravel (70 percent of the gravel is greater than 2.5 cm in diameter)(OGS, 1980d). A pit in the southern part of the area exposes 0 - 2 m of lacustrine silt and sand, overlying approximatly 15 m of poorly sorted gravel with sandier interbeds. The coarse aggregate is approximately 65 percent gravel of which three-quarters may be crushable (Cowan, 1977) Cementation of the gravel in some areas and occasional oversize clasts may be the only quality limitations (OGS, 1980 d).

Pits in this area have been given a moderate to high use rating and a full range of crushed aggregate products may be available (Deike, 1978c). Fine aggregates from at least 2 pits in this area have been found acceptable by MTC for concrete sand.

The Ministry of Natural Resources has estimated (OGS, 1980c; OGS, 1980d) the quantities of reserves in all licenced pits in the Townships of North Dumfries and Brantford (which includes the areas mentioned above) to be about 66 million tonnes. If it is assumed that the annual rate of production from all pits in these two townships is about 1.9 million tonnes and licensed areas have not changed significantly, then presently licenced reserves of sand and gravel in the Brantford / Paris area are about 57 million tonnes.

Estimates by the Ministry of Natural Resources (OGS, 1980c; OGS, 1980d) indicate that the two areas mentioned have an unlicenced area of 514 hectares (including setbacks) containing approximately 111 million tonnes of aggregates (OGS, 1980d).

Road and rail access for local and regional transport of aggregate is very good. The location of the two rail lines, however, will limit the availabilty of a small proportion of the aggregate resources (OGS, 1980d).

6.3.5 Waterford and Simcoe

These two areas are only of minor importance but were considered because of their relative close proximity to the Niagara Region, their good access to rail transport and suggestions by representatives of MTC (Southwestern Region) that if extensively processed, the material could possibly supply some concrete sand.

6.3.5.1 Waterford

There are two gravelly outwash deposits associated with the Galt Moraine meltwater channel located near the town of Waterford. Although the quality of these deposits is extremely varied, there have been a number of problems associated with them including (OGS, 1984a):

1) Low percentage of crushable size gravel
2) Chert varies from 4 to 20 percent requiring beneficiation to produce higher quality coarse aggregate such as HL4.
3) Excess fines making the material generally unsuitable for hot mix or concrete fine aggregate.
4) In the more sandy deposits, the coarse sand gradation requires that the material be blended with finer sand in order to meet hot-mix specifications.

The first area located directly to the west of Waterford, is a gravel outwash deposit exposed at the surface between Waterford and the western boundary of the Town. Several pits operating here produce granular "A", although sand scalping may be required in some areas to meet gradational specifications. Selective crushing or beneficiation may be necessary to produce hot-mix asphalt aggregates. Chert is also present although its distribution is not uniform.

The second area, directly north of the Town, is a beach deposit. It is generally sandy and contains gravelly layers with chert often being high. Limited quantities of crushable gravel are available for granular "A", "B" and "C" (OGS, 1984a).

Although these deposits have been generally unsuitable for concrete sand in the past, it is felt that they might be able to produce this material in some areas if proper processing is carried out.

Estimates by the Ministry of Natural Resources (OGS, 1984a) indicate that these two deposits have a presently unlicenced extractable area of 150 hectares (including cultural constraints) containing approximately 14 million tonnes of aggregate (OGS, 1984a). The quantity of reserves still available in licenced areas is unknown.

6.3.5.2 Simcoe

A few selected deposits of sand and gravel have been found east of Delhi but the quantities of aggregates found are small and they contain high concentrations of fines and chert (in excess of 10 percent) (OGS, 1984b).

The Town of Simcoe rests on a rather large buried delta deposit which was formed by material issuing from a glacial meltwater channel along the Galt Moraine into a shallow glacial lake. Later, rising water levels deposited glaciolacustrine sands on top of this deposit. Water well and other data indicates that approximately 1.5 to 9 m of glaciolacustrine sand, silt and clay overlies 3 to 18 m of deltaic sand and gravel (OGS, 1984b).

Most of the material has high chert and fines content which makes it only generally acceptable for backfill, road subbase and other less demanding uses. However, in places, hot-mix asphalt and concrete sand may be produced if size gradations and quality specifications are met as is evident by one major operation here which has both a pre-mix concrete and asphalt plant (OGS, 1984b).

Neither reserves of suitable material in licensed areas nor resources in unlicensed areas are known but the northern half of the deposit would be extremely restricted because of the close proximity to the Town of Simcoe.

6.3.6 Other Areas in Ontario

The Town of Caledon is one of the largest sources of sand and gravel in Southern Ontario. Estimates by the Ministry of Natural Resources indicate that approximately 109 million tonnes remain in licenced areas (OGS, 1982b). If it is assumed that the average annual rate of production in Caledon is approximately 4 million tonnes and the licenced areas have not significantly changed, then approximately 64 million tonnes of sand and gravel remain in licenced areas.

Estimates of resources outside of currently licenced areas (and all other constraints) are considerably larger. They occupy a total of 3500 Ha. and contain approximatly 560 million tonnes of sand and gravel (OGS, 1982b).

Distance measurements along with discussions from two producers in the Town of Caledon indicate that the transportation costs alone to bring concrete sand as far as Fonthill would be between $9.90 and $11.55 / tonne. Although the quantity of sand and gravel is rather substantial in the Town, these additional costs will make this option undesirable unless all other closer sources become depleted.

Two major potential sources of sand and gravel both of which were mentioned in the Niagara Sand and Gravel Study (Regional Niagara, 1981) are Grey County, including the Saugeen area (Elek and Kearney, 1981); and Bruce County. Both of these counties have large volumes of presently unlicenced resources which would involve long distance movement by rail or ship. Such areas cannot be considered as economically viable sources of aggregates to the Region before the end of this decade (Elek, Personal Communication) unless a much larger demand occurs to justify the development of the resources available and the transportation network required to serve Southern markets.

6.4 Transportation Cost Analysis

An analysis of the costs of transporting aggregates from the source areas mentioned in Sections 6.2 and 6.3 to localized areas of demand in the Region was carried out by Mr. A. Elek of Peat Marwick and Partners Limited.

6.4.1 Present Supply / Demand Scenario in Niagara

A detailed study of the present supply / demand scenario within the Region was undertaken as a preliminary to the transportation / cost analysis carried out by Peat Marwick and Partners Limited.

The main sources of supply of natural aggregates are represented by the licensed sand and gravel pits and dredging operations shown in Figure 1.2. The only land-based producers of concrete sand in the Region are the Steed and Evans and TCG properties operating on the Fonthill Kame represented by locations 5 and 6 respectively in Figure 1.2.

The triangles in Figure 1.2 represent the concentrated users (ie users apart from municipalities and others which distribute their use over a large area) of concrete fine aggregates and include the ready mix producers, concrete block and prestressed concrete products manufacturers which are replotted in Figure 6.3. From previous information obtained from Regional Niagara and conversations with representatives of plants using concrete fine aggregates, it was estimated that together the concentrated users consume approximately 200,000 to 300,000 tonnes of concrete sand per year.

This information was used to analyze the supply / demand scenario and to determine specific points within the Niagara Region in which to carry out the transportation analysis. The distances from the Fonthill Kame to a few of the major individual users were calculated and are shown in Table 6.1. To simplify the calculations, a few of the minor users were excluded from this analysis.

6.4.2 Retail Prices of Concrete Fine Aggregates

The costs of aggregates to consumers is dependent upon:

- production costs at the producing plant
- transportation charges
- profit

Production costs are dependent on a number of factors including:

- the quantity of overburden which must be removed
- the quality of material in-situ
- the capital, operating and maintenance costs of equipment
- labour costs
- property sterilization due to setback requirements etc.

Both production costs and profit are included in the selling prices at the plant. The selling price of concrete sand on the Fonthill Kame (as quoted by an operator) was found to be approximately $7.00 per tonne. The price of similar material at producing plants in the Brantford / Paris, Cambridge and Aberfoyle areas varied from $5.45 to $6.00 per tonne as of January 1985. These were retail prices quoted without the consideration of volume discounts. An average price of $5.50 per tonne was assumed in the transportation analysis due to such discounts.

It is clear that there is a price advantage for concrete sand in areas outside of the Niagara Region.

READY MIX PRODUCERS

1. Red-D. Mix Concrete Co.
2. Transit Mix
3. Clem's Ready Mix
4. Peninsula Ready Mix
5. Regional Ready Mix Concrete Co.
6. Kwik Mix Material Ltd.
7. Premix Concrete

OTHERS (Concrete Block Manufacturers, Precast Concrete etc.)

8. E. Weightman & Sons Limited
9. Bass Block & Building Supplies
10. Modern Exposaic Co. Ltd.
11. Niagara Block Co. Ltd.
12. Fonthill Concrete Products Ltd.
13. Perma-Mix Ltd.
14. Hy-Grade Precast Concrete
15. Northland Bithulithic Ltd.
16. Port Colborne Block Ltd.
17. Canada Building Materials Ltd.

Legend for Figure 6.3 shown on opposite page

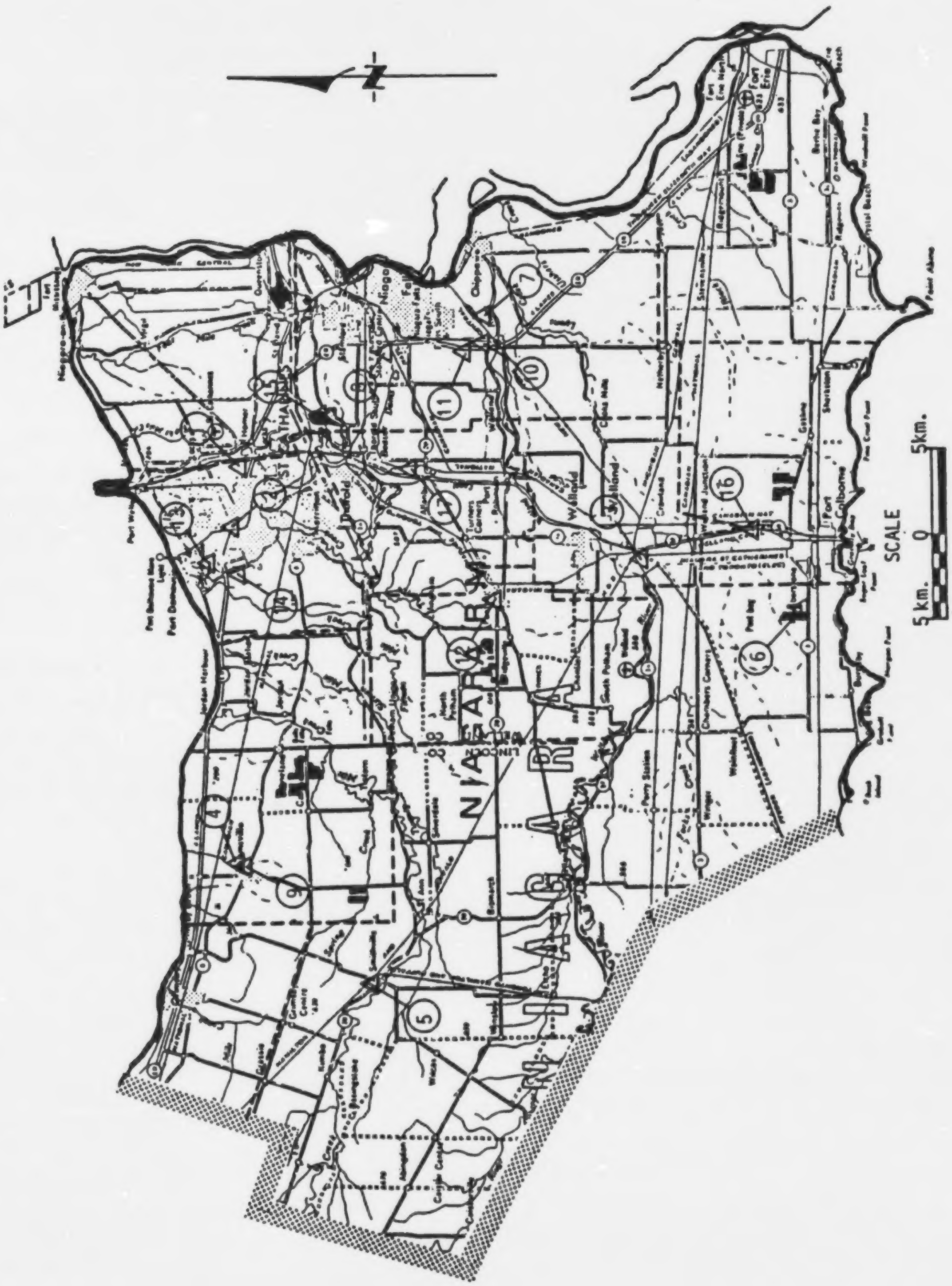

N
NIAGARA
Welland
Port Colborne
Fort Erie
SCALE
5km.
0
5km.

Figure 6.3 - Concentrated Users of Concrete Aggregates in the Niagara Region (See opposite page for legend)

The price of dredged concrete sand from Erie, Pennsylvania landed at Port Colborne was estimated by Erie Sand and Gravel to be approximately $5.00 (U.S.) per cubic yard. Assuming a 'stowage' factor of 1.535 metric tonnes per cubic yard, the equivalent Canadian price would be approximately $5.87 per metric tonne. Terminal storage and handling charges plus truck loading and weighing charges are estimated to be about $2.50 per tonne (Elek, Personal Communication). This would represent a total price of about $8.37 per metric tonne (compared with $7.00 at Fonthill).

6.4.3 Transportation Costs

Transportation costs are found to depend upon two major factors:

- Mode of transportation (road, rail, ship)
- Length of haul

These factors are dealt with in the following subsections.

6.4.3.1 Road

The road distances between the potential sources of concrete sand outside of the Niagara Region (in Ontario) and the various users within the Region were calculated and the results are shown in Table 6.1.

The distances were measured along highways and roads capable of accomodating 5-axle and 6-axle trucks with carrying capacities up to 35 metric tonnes. Considering this requirement, the shortest possible route was chosen in each case. Table 6.2 shows the DIFFERENCES between supply distances from the Fonthill Kame and the alternative areas.

Each incremental kilometre of transportation is associated with an incremental transportation cost. Based on inquiries with trucking companies, this was assumed to be $.06 per tonne-kilometre. This cost implies transportation in large 5-axle or 6-axle tractor-trailors, carrying 27 to 35 metric tonnes per unit.

The incremental cost of $0.06 per tonne-kilometre was multiplied by the distance differences shown in Table 6.2. The weighted average extra road distances, calculated for the entire Region, are shown at the bottom of Table 6.2 along with the corresponding extra trucking charges.

6.4.3.2 Rail

Rail transportation was not evaluated in detail in the analysis because it was found, that in recent years, railways in Ontario have raised their rates for transporting mineral aggregates to levels at which such transportation is no

ROAD DISTANCES IN KILOMETRES

DESTINATIONS	ORIGINS				GATEWAYS	
	FONTHILL	BRANTFORD	CAMBRIDGE(1)	SIMCOE(2)	PORT COLBORNE	FORT ERIE(3)
1. St. Catharines	26	96	94	107	42	43
2. St. Catharines	22	92	90	103	38	47
3. Welland	16	96	117	99	8	37
4. Beamsville	32	78	73	87	56	66
5. Smithville	22	64	79	75	46	75
7. Niagara Falls	25	112	116	120	26	22
8. Niagara Falls	19	105	110	123	32	28
12. Thorold	4	90	105	108	20	43
17. Thorold	13	99	106	117	27	34

---

1) For Kitchener add 15 Km's.

2) For Waterford add 10 Km's.

3) For N.Y. origins add 60 Km's (average).

NOTE: -Diatances from Aberfoyle about same as from Cambridge.

-See Figure 6.3 for Destinations

Table 6.1

DISTANCE DIFFERENCES
VS. FONTHILL (KM)

	ORIGINS				GATEWAYS	
DESTINATIONS(3)	FONTHILL	BRANTFORD	CAMBRIDGE	SIMCOE	PORT COLBORNE	FORT ERIE
1. St. Catharines	-	70	68	81	16	17
2. St. Catharines	-	70	68	81	16	25
3. Welland	-	88	101	83	-8	21
4. Beamsville	-	46	41	55	24	34
5. Smithville	-	42	47	53	24	53
7. Niagara Falls	-	87	91	95	1	-3
8. Niagara Falls	-	86	91	104	13	9
12. Thorold	-	86	101	104	16	39
17. Thorold	-	86	93	104	14	21
WEIGHTED AVERAGE:	—	70	71	80	15	24 60 (US Portion)(2) 84
ADDED TRUCKING COST (per tonne)(1): PRICE DIFFERENCE:		4.20 - 1.50 $2.70	4.25 - 1.50 $2.75		0.90 + 1.37 $2.27	

---

(1) At 6.0 ¢/Km

(2) Plus 6 equivalent Km's for bridge toll

(3) See Figure 6.3 for Destinations

Table 6.2

longer viable to most shippers. The railways' present philosophy is to quote rates marginally below those quoted by truckers. For that reason, the results of the analysis for the trucking of aggregates would not change materially, if rail transportation were to be substituted for trucking in those few instances in which both the producer and user of concrete aggregates had railway sidings served by the same railway company (Elek, Personal Communication) (otherwise addtional handling charges would apply as well). Consequently, the transportation analysis was only based on the trucking of concrete sand from the identified sources in Ontario to the users.

At present, relatively small quantities of aggregates are involved but if demand for sand and gravel in the Niagara Region increases substantially, market conditions could conceivably result in increased use of rail in the future.

6.4.3.3 Ship

Ships are the most efficient mode of transportation for large volumes of aggregates over great distances. For the source at Erie, Pennsylvania as well as the source in Ohio, water transportation was assumed with self-unloaders in the analysis with the material being delivered to the existing dock facilities at Port Colborne. The results of this analysis are presented in Table 6.2.

Another possibility would be the large scale shipping of aggregates through the Welland Canal to the industrial docks at Thorold. Upper Lakes Shipping International (ULSI) (Cliff Abraham, Personal Communication) in Toronto guestimated the following rates for shipping sand and gravel from Erie, Pennsylvania to these docks as:

- For 500,000 tonnes of sand and gravel loaded at 1,000 tonnes per hour - $4.20 per tonne.
- For 1,000,000 tonnes of sand and gravel loaded at 1,000 tonnes per hour - $2.85 per tonne. This figure would be reduced to $2.35 per tonne if loading speed was increased to 2,000 tonnes per hour.

The above costs:

- are in addition to the cost per tonne of material at Erie, Pennsylvania.
- include all seaway costs (only 1 lock at Port Colborne). Seaway fees include a lockage fee of $250 per lock (ships returning in ballast pay $187.50) and $0.31 per gross registered tonne of the ship (for bulk cargo carrying ships). If unloading occurs within the Seaway, an additional $0.14 per tonne is charged for an unloading wharfage fee.
- are based on rates for the 18,500 tonne ship, The James Norris, which now transports stone. It can unload at 2,500 tonnes per hour.
- are based on a round-trip fee from the Thorold docks.

If a larger vessel was used, the price per tonne of sand and gravel could be reduced even further. In addition, the price could be lowered if another cargo such as crushed stone was carried back to the U.S. Detailed economic comparisons of large-scale shipping of concrete sand through the Welland Canal were not carried out because it was felt that it was uneconomic to consider such an option (Elek, Personal Communication - also see Section 3.5.5) particularly when such small quantities of concrete sand would be required.

6.4.4 Analysis / Conclusions

6.4.4.1 Sources in Ontario

The Brantford / Paris area (area 4 - Figure 6.2) is the closest major source of supply of concrete fine aggregates to the Region. Most importantly, some of the licenced properties here are presently not being exploited due to an oversupply of local markets and high transportation costs to other markets. The corresponding extra trucking charges shown in Table 6.2, less the price advantage of $1.50 noted in Section 6.4.2 shows that the supply of Aggregates from these areas would add approximately $2.70 to the delivered price of aggregates, on average, in the Niagara Region. This means close to a 30 percent increase in price compared with today's 1985 delivered price.

The Cambridge and Aberfoyle areas, both having significant reserves would have only marginally higher prices than the figure noted above.

The Simcoe and Waterford areas are also potential sources of supply but their licenced reserves and the number of potential suppliers is much smaller than the other areas mentioned above. Although concrete sand has been produced in the Simcoe area, its reserve estimates are much more unreliable. In addtion, these areas are less advantageous with respect to distance on an average basis. However, users in the southern part of the Region may find these sources to be more suitable than those of Brantford / Paris if suitable quantities of concrete fine aggregates can be found there.

6.4.4.2 Sources in the U.S.

The supply points identified in New York State are relatively small. There is currently no duty on sand entering Canada and therefore, U.S. points were considered in the same manner as Canadian points. U.S. sand imported from New York State compares less favourably with Canadian sand, as indicated in the last column of Table 6.2. Due to longer transportation distances, plus a $0.20 per gross tonne (including vehicle weight) toll on the Peace Bridge, plus the relatively small scale of operation at the supply sources, makes this alternative less attractive unless very low prices can be negotiated with the U.S. suppliers.

Similar considerations apply to the Kent, Ohio source. A Shalersville, Ohio source (northeast of Kent) is about 60 kilometres from the nearest port facilities. This distance, plus the trucking distance from Port Colborne to the points of use is equivalent to distances from other sources. However, the costs of shiploading and transportation costs appear to make this alternative practically infeasible.

The average delivered price throughout the Region of dredged concrete sand from Erie, Pennsylvania delivered at Port Colborne is about $2.37 more per tonne than material from Fonthill. Table 6.2 indicates that the total price increase with respect to Fonthill of this material is marginally less (about $0.50) than the price increase represented by Canadian sand from pits outside of the Region. Dredged sand from Erie could then compete with sand from other land-based pits in Ontario if it was delivered at Port Colborne. It must be remembered that dredged sand from Erie, Pennsylvania may have some inherent quality limitations but it would have to compete with Niagara Bar sand (See Chapter 3.0) in any case.

In summary, the supply of concrete sand to the Niagara Region from sources outside the Region is feasible but at a minimum increased delivered price of about 30 percent.

7.0 RECYCLING, SUBSTITUTION AND NEW TECHNOLOGIES

7.1 Introduction

As scarce high quality reserves of sand and gravel in the Niagara Region gradually become more depleted, many previously uneconomic alternatives will begin to look more attractive. One of the most efficient methods of preserving these reserves in future will be through a general reduction in the demand for natural aggregate products. This will be accomplished through more efficient use of aggregates available through:

- Recycling
- Substitution of other materials
- Application of state-of-the-art construction technologies

These three methods will likely become much more prevalent in future as aggregates become more scarce, concern for preservation of the environment increases and extraction and processing costs increase.

7.2 Recycling

Recycling of aggregates has been prevalant in Ontario for a number of years. A number of recycling processes have been investigated in the past for recycling concrete and asphalt but only the latter has gained wide acceptance.

7.2.1 Recycled Asphaltic Pavement (RAP)

Practical demonstration projects of recycling of asphalt pavements in Ontario began in 1969. Recycled asphaltic pavement (RAP) was studied in earnest during the late 1970's when asphalt costs increased due to the increased costs of disposal and sky-rocketing oil prices caused by OPEC cartel agreements. A corollory to this was the increased processing costs due to price shocks in other energy sectors as well. As recycled asphalt gained wider acceptability, a greater proportion of Ontario's roads consisted of recycled material.

There are numerous examples of recycled pavement use in Ontario including the QEW between Niagara Falls and Fort Erie as well as the Ford Drive Interchange at Oakville.

Today approximately 32 percent of the hot mix used in Ontario roads consists of RAP (See Table 7.1). The MTC has used up to 70 percent RAP on some contracts in northern Ontario. However, many problems with mix design and quality control, as well as environmental concerns, have resulted in new specifications to be drawn up for future use. At present, the MTC will automatically allow up to 25 percent of recycled material to be used and encourages higher RAP useage. A contractor wishing to use a larger proportion of recycled material has to indicate the

MTC HOT MIX TONNAGES FOR 1981-5-6
IN CENTRAL REGION OF MTC (in 1,000 tonnes)

YEAR	CONVENTIONAL MIX	RECYCLED MIX	TOTAL	RECYCLED (%)
1980	2.0	0.7	2.7	25.9
1981	1.7	0.8	2.5	32.0
1982	1.7	0.8	2.5	32.0
1983	1.0	0.7	1.7	41.1
1984	0.7	0.4	1.1	36.3
Total all years	7.1	3.4	10.5	32.3 (Average over 5 years)

Table 7.1

TRENDS IN HOT MIX TONNAGES
IN THE PROVINCE OF ONTARIO (1,000,000 tonnes)

YEAR	NEW CONSTRUCTION	RESURFACING	RECYCLING	TOTAL	RECYCLED (%)
1984	304	44	194	542	35.8
1985	427	84	205	716	28.6
1986	100	74	211	385	54.8

Table 7.2

source of such material. If the source is known, then a higher proportion is permitted (but only up to 50 percent), although normally the source(s) of stockpiled recycled materials in the yards of hot mix plants is not known.

Demonstration and research programs by the MTC in all parts of Ontario have identified several technical problems with the use of RAP including:

- greater than anticipated degradation of the reclaimed materials
- as the percentage of RAP increases beyond 25 percent, finer, higher quality virgin aggregates are required
- low penetration of asphalt cements found in recycled mixes and quicker aging and enhanced brittleness of recycled pavements
- oversize problem with RAP
- variability of asphalt cement content and gradation of RAP, due mostly to methods and techniques of pavement removal (cold milling, cold planing, full depth removal, etc.)
- blue smoke pollution

Due to some of the above cited problems, recycled hot mix is allowed only in binder courses in Ontario provincial highway systems. This limitation is also adopted in many municipal jurisdictions in Ontario as well.

MTC policies on the use of RAP will invariably dictate the outcome of any predictions as to the degree of conservation which may be achieved in the future. Table 7.2 shows the current MTC plans for hot mix recycling in the Central Region (including the Niagara Region) over the next two years.

The Ministry of the Environment and the MTC have drafted guidelines with respect to control of blue smoke emissions from drum dryer mixers. There are about 130 conventional stationary hot mix plants in Ontario, and about 20 Drum Mixers, most of which are portable. For economic and technical reasons, the drum type mixers are preferred for RAP. Blue smoke results when the ratio of virgin to recyclable materials falls below 1.0. Therefore, the MTC "...has made a commitment to limit recycling ratios to 50/50 (greater than 25 percent with special permission) in Districts 1 to 9..." which includes the Niagara Region (Lynch, 1984).

Economics will influence future demand and growth of RAP. If the proportion of recyclable material to be used in hot mix applications is limited, then the cost of removal and disposal offsets the salvage value of the recycled material. For small percentages of RAP, the net savings for the contractor may be minimal, after making allowances for overhead increases, etc. Hence, the impetus for a growth in recycling will come from three major sources:

1) Increase in the price of asphalt cement

2) Decrease in the availability of suitable virgin aggregates and quality asphalt cement (this is a current trend in the Niagara Region and one which is likely to continue into the future).

3) Increasing cost of disposal

Although MTC anticipates using 50 percent RAP by 1986, overall growth to that level will be much slower since hot mix plants in Ontario currently average only about 10 percent RAP in their operations.

The trend towards increased use of RAP in asphaltic concrete for road binder courses is already in motion in the northern parts of the Province. In southern Ontario, closer environmental control will limit that trend somewhat.

With the prevailing lowered oil prices on the world markets, it is expected that the average RAP content in hot mixes will remain at 10 percent. By 1990, this percentage may increase, reaching a maximum value of 30 percent by the end of the forecast period, particularly as the availability of virgin aggregates becomes scarce. This would represent a savings of total aggregate requirements (for all products) for the Niagara Region of less than 2 percent.

It should be noted that any increase in RAP will not only reduce the demand for either asphalt sand or screenings in the Niagara Region but it may result in a change of source. This is because as RAP increases, even beyond 10 percent, the requirements for much cleaner aggregates also increases. It is felt that neither natural asphalt sand from Fonthill or screenings may be able to satisfy this requirement (Katona, Personal Communication). Unless an adequate quantity of dredged material or foundry sand of suitable quality is found, material might have to be brought in from outside of the Niagara Region.

Further research is necessary in new recycling technologies (such as heater/scarifier repavers) and the use of additives (such as softening agents). in addition, the long term consequences of any deviations from current policies of restricting RAP to 50 percent of the total mix, both in terms of production, quality control and field performance, as well as costs (present and future for increased maintenance, shortened pavement life, etc.) and economics (current savings versus future expenditures) should be examined.

7.2.2 Recycled Concrete

It is estimated that 72,000 tonnes of concrete debris suitable for recycling is produced annually in Hamilton-Wentworth. If this is proportioned on a population basis, then approximately 64,000 tonnes of concrete debris suitable for recycling is produced annually in the Niagara Region.

In Ontario, crushed concrete is regularly used for granular base and the City of Victoria, British Columbia has successfully used it as a replacement for gravel (Swanson, 1983).

One of the main problems of recycling concrete as concrete aggregate is the fact that when old concrete is crushed for coarse aggregate, a large amount of fines are often generated (approximately 20 percent) (Hansen and Narud, 1983). In addition, the material contains gypsum and lime product contaminants (OECD, 1977).

Generally, Portland cement concrete made with such an aggregate exhibits lower strength than corresponding concrete containing normal aggregates. It has also been shown that both the compressive strength and modulus of elasticity are lower in concrete containing recycled aggregate, with these differences being enhanced at lower W/C ratios. The use of water reducing agents and higher cement contents should result in higher strengths (Ramachandran et. al., 1981).

One of the main differences between recycled concrete and conventional concrete is the higher water absorption of the recycled samples due to the presence of increased amounts of cement paste.

The workability of concrete made with natural aggregates is similar to that of crushed concrete containing natural sand. If crushed concrete is mixed with fines made from the recycled concrete it would result in higher (5-10%) water requirements. This would be expected because of the higher amounts of hydrated cement particles involved. Also, the drying shrinkage of concrete made with recycled concrete is higher by 10 to 30 percent than the control concrete. However, the durability of concrete containing recycled concrete aggregate is similar to that of the control containing normal aggregates.

"Further knowledge has to be accumulated on durability, creep, wetting expansion and other related properties before recycled concrete can gain wider acceptance" (Ramachandran et. al., 1981).

Crushed concrete will continue to represent a small proportion of granular base requirements for the Niagara Region (estimated at 0.1 percent) and it will not likely be used as an aggregate in new Portland Cement concrete, at least for the foreseeable future.

7.3 Substitution

Another method of reducing the demand for aggregates is through substitution of a wide variety of waste materials. Some types of industrial by-products are available in large quantities (particularly in the Hamilton area) and, if transportation costs are favourable, it might contribute to solving some of the aggregate supply problems in the Niagara Region. There are three major constraints on the use of waste materials:

1) They must fulfill the engineering requirements in terms of physical properties.

2) They must not contain excessive amounts of deleterious components which might cause problems in use.

3) They must be economically attractive to cover handling and processing costs.

Some materials which have been used include blast furnace slag, flyash, and glass to a minor extent. Many of these materials have been used successfully in field trials throughout the world.

There are a number of advantages to using waste products including:

1) Conservation of high quality natural aggregates
2) Conservation of the energy which would be used to mine and transport the aggregates which would otherwise be needed.
3) Elimination of unsightly piles of these waste products
4) Reduced disposal costs

Several of the products which can be substituted for aggregates are dealt with in more detail below.

7.3.1 Slag

There are a number of different types of slag which have been substituted for aggregates in the past. The types which have the greatest applicability to the Niagara Region include blast furnace slag produced by Stelco and Dofasco Limited in Hamilton and marketed through National Slag Limited, and steel-making slags produced by both Stelco and Dofasco and the Atlas Steel Division of Rio Algom Limited in Welland.

7.3.1.1 Iron Blast Furnace Slag

Iron Blast Furnace Slag is by far the most important of the numerous types of slag produced. It consists of silica and alumina from iron ore combined with calcium and magnesium oxides from the flux stone (Lewis, 1982) and can be grouped into three major types (Emery, 1980; Lewis, 1982):

1) Air-Cooled Blast Furnace Slag (ACBFS)
2) Pelletized Slag
3) Expansive (Foamed) Slag
4) Granulated Slag

Only the first two have general applicability to the Region.

1) Air-Cooled Blast Furnace Slag (ACBFS)

Air-cooled blast furnace slag is formed by solidification of molten slag under ambient conditions. The slag is then dug out, crushed and screened (metallics are removed) to various sizes. The slag crushes to angular, roughly cubical particles with pitted surfaces and is about 20 percent lighter than natural aggregates (Lewis, 1982). Air-cooled blast furnace slag (ACBFS) has a number of advantages including (Emery, 1982):

- low compacted bulk density (reduces dead load, lateral pressures and transportation costs)
- high stability (CBR = 100%)
- high friction angle (approximately 45 degrees)
- can stabilize wet, soft underlying soils at early construction stages
- it is placeable in almost any weather

- it has good resistance to weathering and erosion
- it is free draining and non-frost susceptible
- there is almost a complete absence of settlement after it is compacted
- it is non-corrosive to both steel and concrete
- it does not polish and has high skid resistance
- it is not subject to harmful cement-aggregate reactions (Lewis, 1982)
- it is hydrophobic in nature (thus assuring adhesion of bituminous materials) (Lewis, 1982)

Disadvantages include:

- high asphalt and portland cement requirements (due to the vesicular surface of the slag)
- high absorption

Air-cooled blast furnace slag can be used for granular base, rail ballast, roofing granules, asphaltic concrete (black top), concrete and masonry units. Asphaltic concrete has a high skid resistance but its use is limited because of the high asphalt cement content required.

ACBFS is often used as coarse aggregates in all types of concreting applications associated with road construction pavements, precast and prestressed units, foundations, curb-and-gutter and ready-mix although little, as yet, has been used in Ontario.

For concrete applications, ACBFS mixes compare favourably with ordinary mixes in compressive and flexural strength and offer superior fire resistance. Durability and aggregate paste bond are excellent but workability requirements may involve proportioning to allow for slightly more sand and water (Emery, 1982).

ACBFS was once produced by the now-defunct Algoma Steel plant at Port Colborne. The material, at that time, was approved for use on MTC projects and was used by the St. Lawrence Seaway Authority as granular base on its roads for the Welland By-Pass Channel (Regional Niagara, 1981).

By far the greatest amount of ACBFS that is currently being produced is the material from Stelco Limited and Dofasco Limited in Hamilton, Ontario. Together they produce about 1.35 million tonnes (Collings and Wang, 1980). Virtually all of this material is taken by National Slag Limited, also of Hamilton, who are a well-recognized pioneer in the slag-processing field. However, there is the possibility that sometime in future Stelco and Dofasco could process and sell more of their material directly.

2) Pelletized Slag

National Slag Limited in Hamilton has developed a pelletizing process in which slag droplets are formed by applying small amounts of water to chill the slag as it is thrown through the air by a rapidly revolving finned drum. This produces spherical pellets with a relatively smooth, sealed surface from 150 um to 13 mm in diameter, with the bulk in the minus 10 mm to plus 1 mm range (Emery, 1980). Approximately 3 to 4 percent pass the 200 mesh, 7 to 8 percent pass the 100 mesh and 50 percent both passes and is retained on the number 16 mesh. Although pelletized slag used in lightweight structural concrete has a higher unit cost (Emery, 1980), there are definite advantages of pelletized slag over most expanded slags because of the smooth, coated particles produced including: (Emery, 1982)

- a smoother surface in concrete
- reduced water absorption and cement demand

National Slag Limited produces 1.0 to 1.5 million tonnes of pelletized slag per year, of which 60 to 70 percent is used for granular base material. They also produce approximately 150,000 tonnes of a perfectly acceptable sulphate-resisting slag cement consisting of a mix of 25 to 35 percent slag cement to Portland Cement although higher ratios can be achieved.

A 50 percent cementitious hydraulic slag / 50 percent Type 10 Portland Cement (normal Portland Cement) blend has equivalent sulphate resistance to type 50 Portland Cement (sulphate resisting cement) (Emery, 1980) and it is now being used in concrete applications requiring sulphate resistance such as in foundations and sewer pipes.

Pelletized slag represents approximately 10 percent of the granular base requirements in Hamilton-Wentworth. Granular "A" from National Slag is currently being sold for about $5.50 per tonne and Granular "B" for $5.25 per tonne but the yield is 20 percent more due to the lower bulk density of the material.

Pelletized slag has been used as an aggregate in some concrete products but it is felt that it will not replace sand in normal ready mix (Westoby, National Slag Limited, Personal Communication).

Pelletized slag may be a possible source of Granular "A" to the Niagara Region, but it will unlikely be able to compete with the Fonthill Kame or quarries even in the northwestern part of the Region.

7.3.1.2 Steelmaking Slags

Steelmaking slags are the by-products of the processing of molten iron (known as hot metal) and scrap (known as cold metal) into the desired type and grade of steel in steelmaking furnaces. The different types of furnaces, grades of steel produced and individual furnace operating practices result in variations in composition and properties at different mill locations. Steelmaking slags are composed primarily of calcium silicates, calcium aluminoferrites and fused oxides of calcium, iron, magnesium and manganese. They are much heavier, denser, harder and less vesicular than air-cooled blast-furnace slags (Lewis, 1982).

Steelmaking slags have some advantages in asphalt such as (Emery, 1980):

- higher skid resistance than traprock
- higher stripping and rutting resistance
- high heat retention
- high stability

Although there are some advantages to using steelmaking slags in some aggregate products, a few major disadvantages have precluded its use as a concrete aggregate. Some of these disadvantages include:

- high expansive potential
- the material is often contaminated with steel works rubbish such as refractories (MTC limits total contaminants to 3 % and wood to 0.5 % by weight (Emery, Personal Communication))

The main uses for steelmaking slags include railroad ballast, highway bases and shoulders, paved area bases, fills and asphalt mixes (Emery, 1980).

Steel slag has been used in the Toronto-Hamilton area for binder and surface coarse asphaltic concrete mixes since 1969. A large growth in its use has occurred during the past 5 years which has been ...related to both its general acceptance for municipal street work and increasing MTC highway applications in dense-graded friction course (skid resistance) and open-graded friction course (skid resistance and tire-pavement noise reduction)...(Emery, 1984b). There are currently several suppliers of steel slag aggregate in Southern Ontario such as Red-D-Mix and Steetley Industries (Emery, 1984b).

There have been virtually no problems with quality and durability when using steel slag in asphaltic concrete mixes and any surface pop-outs observed have been minor. The skid resistance of asphaltic concrete using steel slag has been found to be superior to that of the usual wear-resistant surface coarse mix containing trap rock. Indeed, for Ontario, steel slag asphaltic concrete mixes appear to be the most skid resistant aggregate currently available and are included in MTC specifications (Emery, 1984b). Steel slag is also used in hot mixes for winter patching because it retains heat, has a high unit weight, the stability of the material tends to hold patches in place and it has higher skid resistance than traprock (Emery, 1984b).

The most important applications for steel slag asphalt mixes are:

1) Surface coarse mixes (due to excellent skid and good wear resistance)
2) Industrial paving (high stability and rutting resistance)
3) Winter patching
4) Slurry seals
5) Binder coarses

Satisfactory stabilized bases consisting of 60 percent blast furnace slag (0 - 60 mm), 25 percent LD steelmaking slag (0 - 15 mm) and 15 percent granulated blast furnace slag have been placed and compacted with standard highway equipment (at 10 percent water content) with excellent results (Emery, 1980).

Steel slag is presently being used in hot mix as a portion of the coarse aggregate (approximately 30 percent) by one major producer in the Niagara Region.

Slater Steel Industries, Dofasco Limited and Stelco Limited all of Hamilton, Ontario together produce approximately 1.7 million tonnes of steel slag annually. The bulk (approximately 73 percent) of this material is recycled but approximately 400,000 tonnes has potential use in highway construction, asphalt and rail ballast (from Collings and Wang, 1980).

The Atlas Steel Division of Rio Algom Limited in Welland is, at present, the only slag producer in the Niagara Region. They accumulate approximately 27,000 tonnes per year of electric arc furnace slag. Although this material is presently being disposed of, there may be a potential in future to use some of it in asphalt aggregate or landfill (Collings and Wang, 1980).

7.3.2 Flyash

Flyash is a by-product of coal burning at generating stations. It has primarily been used as fill (Regional Niagara, 1981), although it can also be used in certain cement products. In France, Germany and Belgium, approximately 10 percent of annual cement manufacture is being satisfied by wastes (Gutt and Smith, 1975). In these countries, flyash is being used both as a pozzolanic material in the production of Portland pozzolanic cements directly at the batching plant and as aggregate (in some cases to partially replace concrete sand). In Ontario, flyash is only being used as a pozzolanic material in cement although it could be used to partially replace concrete sand. Other uses have included aerated concrete blocks.

The closest major source of fly ash to the Niagara Region is the Nanticoke generating station which is about 80 kilometers from St. Catharines (Regional Niagara, 1981). The possibility of extensively using this material in concrete is precluded by the rather high transportation costs which would be involved in bringing the material into the Niagara Region.

7.3.3 Foundry Sand

The only material of any quantity being produced in the Niagara Region itself is waste foundry sand from the General Motors of Canada plant at St. Catharines.

This material is an evenly-graded silica sand which is being imported into the Region by ship from Michigan. Once used, it contains various products from the foundry process including carbon, refractory material, phenols (Cowan, Personal Communication) and glass slag (Rogers, Personal Communication).

Approximately 200,000 tonnes of this so-called 'black sand' is taken by Walker Brothers Quarries of which approximately half is suitable for re-use (Cowan, Personal Communication). The material is dry screened and about 30 percent is sold to the asphalt industry. Approximately 25 percent of the fine aggregates used by one hot-mix producer in the Niagara Region is recycled foundry sand and MTC has used the material during the construction of the new highway 406.

The rest of the material is sold as sand fill (Regional Niagara, 1981) because of its excellent compactability (Cowan, Personal Communication). If there is no processing beyond the screening of the material, it is unsuitable for use as fill near a water course or for concrete aggregate. In addition, it is not possible to use it where it would be in contact with metal conduits or reinforcing rods because of its corrosive nature (Regional, Niagara, 1981).

It may be possible to use recycled foundry sand in concrete if it was extensively washed and beneficiated, although disposal of the effluent which would be created by washing would be another major problem which would have to be addressed. The environmental and processing costs of recycled foundry sand would make it highly unlikely that it would be used as fine aggregate in concrete before the end of the century. In addition, washing would allow 100 percent of the sand to be recycled and therefore would likely be unavailable in any case.

Foundry sand presently represents approximately 1/4 of the fine aggregates required in asphaltic concrete in the Niagara Region (Katona, Personal Communication). Even if 100 percent of all of the foundry sand not being recycled now was used to replace natural aggregaes, this would represent a reduction in the total cumulative demand for all aggregates by the year 2000 of only 1.9 percent.

7.3.4 Other Substituted Products

Other products which might be considered include glass and materials obtained from demolition.

It is estimated that approximately 20,000 tonnes of waste glass is produced in the Niagara Region, most of which goes to landfill sites as part of refuse or incinerator residues. Waste glass is often quite variable in composition and is contaminated with dirt, labels and other substances. In addition, crushing of the material produces elongated particles (Ramachandran, 1981).

Glass has been used in asphaltic concrete (trials only) but Portland cement concrete made with such material is extremely alkali-reactive (although this problem can be partially aleviated by using low-alkaline cement). Glass has been used where concrete is sufficiently porous to allow expansive reaction and acceptable concrete blocks have been made by replacing a portion of the natural sand and gravel with glass (Gutt and Smith, 1975).

Until resource recovery operations in Ontario develop, little utilization of waste glass is anticipated and recycled glass will probably directly compete in any case (Emery, 1984).

7.4 New Technologies

The use of geotextiles, advanced building techniques and better methods of preserving existing structures may all help to reduce the demand for some aggregates in future.

There has been a great increase in the types of geotextiles being produced in the last few years. Plastic grids have been developed which can be placed on the subsurface or road bed or between an existing roadway surface and an asphalt overlay. Such techniques use less asphalt yet produce a stronger road surface (Haas, 1983). There are a number of advantages associated with geotextiles:

- a thickness savings of up to 100 mm of asphalt material can be achieved
- there is a minimization of fatigue cracks
- less maintenance is required due to reduced rutting and cracking
- up to double the number of axle load repetitions as well as higher axle load limits can be achieved

The major disadvantage of using these materials is their relatively high cost but as the cost of natural aggregates increases, it is anticipated that the use of geotextiles will also increase.

New building techniques developed over a number of decades now emphasize the use of steel rather than other materials. This has resulted in a reduction in the quantities of concrete which were previously required. Advances in building techniques are continuing to reduce the quantities of structural materials being required although this has levelled off in recent years.

One of the more efficient methods of reducing aggregate requirements in future will be through advanced techniques in the preservation of existing roads and structures. Such techniques reduce maintenance, repair and replacement costs and their inherent aggregate requirements. For example, concrete modified with synthetic rubber latex can improve bridge surface durability because it forms a barrier that slows the rate of penetration by moisture and road salts (Civic Public Works, 1982).

7.5 Affects of Recycling, Substitution and New Technologies on the total Aggregate Demand in the Niagara Region

If it is assumed that use of recycled asphalt pavements (RAP) will increase from the current 10 percent to 30 percent by the year 2000, then the use of this material will probably represent a savings of less than 2 percent in the overall cumulative aggregate requirements for the Region by the year 2000.

If all of the waste concrete being produced in the Region was recycled, this would represent an aggregate savings of only 2 percent. A more likely scenario is that waste concrete will represent only about 1 percent of the Region's cumulative aggregate requirements by the year 2000 and it will be used exclusively as granular base.

Virtually all of the slag material being produced at Hamilton is either being recycled or is already being used as a pozzolan in cement or as aggregate. Therefore these materials are unlikely to have any impact on the overall cumulative aggregate requirements for the Region. The steelmaking slags being produced at Welland, if ever used, would represent a reduction in aggregate usage of less than 1 percent.

The environmental problems involved in washing the General Motors foundry sand and the likelihood that such material would be recycled if washed anyway, indicates that increased use of this material as an aggregate is unlikely.

Advanced products such as geotextiles and the use of new building techniques will not likely have a great impact on the overall reduction of aggregate requirements in the Niagara Region but may help in a modest way. The most optomistic projection would indicate that all such techniques will reduce the cumulative demand for all aggregates by a maximum of 3 percent by the year 2000.

In conclusion, it is therefore anticipated that recycling, substitution of waste products and the use of new technologies in construction can at most reduce total cumulative demand for aggregates by about 7 percent. Of all the techniques studied, only advanced building techniques is likely to have any significant impact on the demand for concrete fine aggregates. It is anticipated that techniques such as increased use of steel and high strength lightweight concrete will reduce the annual demand for concrete fine aggregates by an overall percentage of about 5 percent by the year 2000 and 10 percent by the year 2015.

8.0 SUMMARY AND CONCLUSIONS

8.1 Introduction

The present supply of natural aggregate products from the Fonthill Kame as well as a number of possible alternative sources for these products have been discussed in detail in the preceding Chapters. The prevailing issue in this Study has been whether the Fonthill Kame, which is located in an important tender fruit-growing area and is presently the major source of sand and gravel in the Region (and the only land-based source of concrete sand) can be phased out and eventually be replaced by some or all of the following alternatives:

1) Dredged materials from the Niagara Bar
2) Crushed stone and manufactured sand from quarries in the Region
3) Other sand and gravel deposits in the Niagara Region
4) Importation of sand and gravel from areas outside of the Region

In addition, recycling, substitution of waste products and new construction technologies were evaluated as to their ability to affect the future supply / demand scenario for various aggregate products in the Region.

To qualify as a viable alternative, each of these possible sources was evaluated in terms of quality, quantity and its general economic viability. Conclusions drawn from this work along with specific recommendations are summarized in this Chapter.

8.2 Demand for Aggregates in the Regional Municipality of Niagara

An optimistic (ie. high growth) projection of the demand for aggregates from all sources in the Region indicates that the yearly demand is likely to remain fairly constant (see Table 2.7) although it will increase slightly from 3.4 to 3.7 million tonnes over the remainder of this century. It was calculated that a cumulative demand of approximately 60.5 million tonnes of all aggregates would be required from the end of 1983 to the end of the year 2000. Studies of the demand for aggregates in the Niagara Region have shown that approximately 18 percent of the total aggregate requirements are met by sand and gravel from land-based pits or dredging. If it is assumed that this trend will continue over the forecast period, then 11 million tonnes of these aggregates will be required in the Region by the end of this century.

The demand for concrete (and concrete aggregates) in Ontario is a function of the Gross Provincial Product and follows the model described in Section 2.3.3. If it is assumed that the concrete demand in the Region is 3.3 percent of Ontario's concrete demand (based on the historical relationship of aggregate usage in the Niagara Region and Ontario - see Section 3.3) , then the annual consumption of all concrete aggregates (plus that used in road construction) will increase from 770 thousand tonnes at the end of 1984 to 1330 thousand tonnes through the year 2000.

If it is further assumed that the consumption of fine concrete aggregates (including concrete sand from the Fonthill Kame and the Niagara Bar as well as quarry screenings used in concrete products) represents 45 percent by weight (weighted average of fine aggregate versus coarse aggregate useage by all major ready-mix, concrete brick, block and pipe manufacturers) of the total consumption in the Region, then the annual concrete fine aggregate requirements for the Region will increase from 349 thousand tonnes in 1984 to 596 thousand tonnes by the end of the year 2000, representing a total cumulative demand of 8.1 million tonnes (See Table 2.8).

It should be noted that the latest figures indicate that concrete sand production from Fonthill was about 214,000 tonnes in 1984. The concrete fine aggregate consumption noted above was calculated to be about 349,000 tonnes in 1984 but this, of course, does not include either dredged sand from the Niagara Bar being sold as concrete sand or the 70,000 tonnes (estimated) of concrete fine aggregates from quarries presently being used in concrete products (see Table 8.1). Despite the recent decline in concrete fine aggregate demand, it is felt that demand projections for 1984 are within about 12 percent of actual. However, the long term projections given above may be overstated (conservative - high demand estimate) and will be used only for illustrative purposes.

8.3 The Fonthill Kame

The Fonthill Kame is a meltwater deposited stratified mound of sand and gravel located in the Town of Pelham, Ontario. It is located in in a very significant tender-fruit growing area and is important for environmental, scenic and recreational purposes. The Kame is the major source of sand and gravel in the Region and presently supplies 0.5 to 0.6 million tonnes or 80 to 90 percent of the Regional demand for sand and gravel.

The Kame produces 60 percent of all of the Group III fine aggregates (see Appendix II) produced in the Region in spite of the fact that the quality of the material before processing is somewhat less than that of similar material being used in most other areas of Southern Ontario (see Section 5.3.1). The Kame is presently the only land-based supplier of concrete sand (200,000 to 300,000 tonnes per year) and one of the major suppliers of asphalt sand (30,000 to 40,000 tonnes per year) in the Region.

Presently licenced reserves in the three operations on the Kame are about 2 million tonnes and are expected to last only 3 to 4 years. However, potential selected resources outside of these areas could be as much as 86 million tonnes of which 60 percent (estimate based on information from the Regional Niagara Planning Staff) or 52 million tonnes may be suitable for concrete sand. This is more than enough to satisfy all of the sand and gravel requirements of the Region well into the next century.

8.4 Dredging of the Niagara Bar

The Niagara Bar is a large deposit of granular material in Lake Ontario. It straddles the U.S. border at the mouth of the Niagara River (See Figure 3.2).

At present, there is only one dredging operation remaining on the 'Bar' providing less than 2 percent of all aggregates, 11 percent of the sand and gravel and 18 percent of all Group III fine aggregates produced in the Region.

Dredged material from the Niagara Bar contains a number of undesirable constituents such as chert, manufactured glass, slag, sandstone particles and pebbles as well as minor light materials such as wood and coal which limit the suitablity of the deposit for certain aggregate uses. Some of the lighter materials are floated off during the dredging operation but research by the Hydro-Electric Power Commission of Ontario (Appendix IV) and petrographic analyses of material from stockpiles at Queenston in this Study have shown that the oversize fraction still clearly exceeded the 5.0 percent limit for deleterious components in aggregates for mass concrete (Hydro-Electric Power Commission specification). The fine aggregate fraction which represents about 95 percent of the dredged material from the Niagara Bar contains about 3.3 percent of these undesirable components although the chert content often greatly exceeds the one percent limit. Even though not all cherts are equally reactive, more beneficiation will be required if dredged material from the Bar is used extensively as a substitute for land-based concrete sand in Portland cement concrete.

Analyses of grain size results of materials taken directly from the Bar have shown that it is gradationally unsuitable for concrete sand although it can be used for lower grade products such as plaster and masonry sand, winter sand and other uses which allow relatively fine-grained materials. The total reserves of dredged materials suitable for these purposes is estimated to be 160 million tonnes (Table 3.4).

Since concrete sand requires a coarser gradation and coarse materials are relatively rare on the Bar, gradationally acceptable concrete sand produced totally from dredged materials is in relatively short supply. To produce an acceptable concrete sand, coarser fractions only obtainable at the mouth of the Niagara River (see Figure 3.16) must be mixed with other sand from the Bar in a 1 to 2 proportion. This mixing can potentially generate approximately 6.9 million tonnes of gradationally acceptable concrete sand. It should be noted here that no samples have been collected of the coarse materials from the mouth of the Bar and this last reserve estimate was based on information supplied by the dredging boat captain.

Most of the Niagara Bar sand is often too fine and, without extensive processing contains deleterious components which limit its use as the fine aggregate component in Portland cement concrete. However, this material has been used in the past in mass concrete applications by the Ontario Hydro Electric Power Commission under strict quality control. Such materials can (and are being used) in Portland cement concrete if:

1) The sand is mixed with coarser fractions to produce a more gradationally acceptable material. The source of these materials can be from the small area near the mouth of the Niagara River or from land-based pits or quarries, in which case, there might be no forseeable limit for the potential use of dredged material in Portland cement concrete.

2) The percentage of deleterious materials is reduced to meet specification limits. This can be done again through mixing of aggregates from land-based sources or through more extensive beneficiation of the Bar sand itself.

In evaluating the potential of the Niagara Bar sand for use in Portland cement concrete, it should be remembered that the quality of the sand deposits in the Fonthill Kame is also less than desirable. At one time, sand produced from the Kame did not meet Ontario Ministry of Transporation and Communications specifications for concrete sand.

8.5 Crushed Stone and Manufactured Sand From Quarries

Crushed stone currently represents by far the largest amount of aggregate products in the Region. Quarries in the Niagara Region produce about 3 million tonnes per year. Although aggregate production from all sources has generally declined in recent years, the percentage of total production by quarries has steadily increased and now accounts for about 82 percent of total aggregate production in the Region (Figure 1.4).

Quarries presently supply a wide range of aggregate products including greater than 95 percent of clear aggregates, 90 to 100 percent of coarse aggregates, 20 to 25 percent of fine aggregates, 55 to 85 percent of granular base and subbase and 75 percent of all other aggregate products in the Region.

Crushed stone reserves in the Region are very large. It is estimated that there are approximately 230 to 270 million tonnes of suitable limestone remaining in presently licenced areas (excluding all constraints), of which, 108 million tonnes is suitable for concrete fine aggregates. Presently unlicenced resources are considerably larger and are estimated to be about 6.1 billion tonnes, of which, 3.3 billion tonnes is suitable for concrete fine aggregates. It is quite clear, that even at greatly increased rates of production, limestone reserves will be more than adequate to satisfy all aggregate product requirements for the foreseeable future.

Quarry screenings (as an unprocessed 'by-product' of crushing operations) are now being produced in large quantities throughout the Region and some is being used in Portland cement concrete. Screenings currently represent approximately 17 percent of the fine aggregates being used in concrete produced in the Region.

Due to the high percentage of fines found in such material, screenings cannot replace concrete sand (without extensive fines removal and other processing) and it is unlikely that the use of such materials will increase significantly over present rates of consumption.

On the other hand, 'manufactured sand', as a quality-controlled, processed, fine aggregate produced from quarried stone can represent a potential substitute for concrete sand. Although it was once produced by Walker Brothers Quarries a few years ago, manufactured sand is no longer being produced anywhere in the Region.

It is technically feasible to produce concrete of suitable strength using only quarried limestone aggregates but most users of the product have found that the major problem with it has been one of workability. This problem, related to the angular nature of the particles, can be alleviated through advanced crushing techniques (such as the Hazemag system) and the use of air entrainment or the addition of a pozzolan. Due to this additional processing, the costs of producing a suitable concrete totally from limestone averages about $4.00 more per tonne of concrete than using only natural sand. This is due to the additional crushing and screening involved in producing a manufactured sand, the additional cement required due to the higher particle surface area as well as the requirement for additives to overcome the inherent harshness of the mix. Both the producers and users of ready mix feel that, at this time, these additional costs make it unattractive to produce a concrete totally from crushed stone. It is generally felt that, in the Region, it will be more economically attractive to blend natural sand with manufactured sand (or a small amount of screenings) to a maximum of 50 percent of the concrete fine aggregate component in Portland cement concrete even if this means importation of natural sand from outside of the Region.

Since there is no real problem with increasing the quantity of quarried fine aggregates in ready-mix to a maximum of 50 percent and bricks and blocks can use 75 percent or more, there is a great potential to extend the life of available concrete sand from the Fonthill Kame through greater use of quarried fine aggregates.

8.6 Other Land-Based Sources in the Region

Although the Fonthill Kame is the major producer of natural sand and gravel, other land-based sources within the Region are currently providing some low specification aggregate products such as granular base and subbase and all types of sand fill.

There are six licenced sand and gravel pits operating outside of the Fonthill Kame with total reserves estimated to be less than 550,000 tonnes. These sources provide about 37,000 tonnes of sand and gravel per year which represents less than 1 percent of the total aggregates and 5 percent of the total sand and gravel produced in the Region.

Suitable unlicenced resources outside of the Fonthill Kame are scarce. Within the Region, the only other resources that are considered to be of "Primary Significance" on a Regional basis lie in the City of Port Colborne and the Town of Fort Erie. They are small deposits of beach and deltaic sand and gravel estimated to contain about 4 million tonnes of material, some of which may be suitable for concrete sand. However, the small size of the deposits may discourage their development on a commercial basis.

Reserves of "Secondary Significance" on a Regional basis are found as shallow glaciolacustrine deposits of fine sand and gravel in the Township of Wainfleet and the City of Welland as well as the glaciolacustrine delta sometimes referred to as the St. David's buried gorge in the City of Niagara Falls. The deposits of Wainfleet and Welland are only generally suitable for low specification construction aggregates such as granular "A","B" and "C", although with proper beneficiation, some concrete sand might be produced.

The St. David's deposit in the City of Niagara Falls has traditionally provided most of the natural aggregates in the Region outside of the Fonthill Kame but the coarser materials have now been extracted and fine reddish sands suitable only for fill remain. The Ministry of Natural Resources has indicated that some granular "C" material and concrete sand may be available in scattered locations at greater depths.

Total reserves of "Secondary Significance" on a Regional basis in these three municipalities amount to about 17 million tonnes.

Although sand and gravel reserves of "primary" and "secondary" significance are quite small, "tertiary" reserves are large but not economically significant and amount to approximately 1,925 million tonnes. However, they are, in general, only suitable for low specification construction aggregates, and little, if any, may be suitable for concrete sand.

In conclusion, land-based sources may possibly supply some 8 million tonnes of concrete sand (Regional Niagara) in total but these sources cannot be relied upon since their relatively small size may discourage their development on a commercial basis.

8.7 Importation of Aggregates

Small amounts (less than 4,000 tonnes) of natural sand and gravel are currently being imported into the western part of the Region from the Brantford / Cambridge areas. If the Fonthill Kame is no longer able to produce concrete sand and other natural aggregate products, then a shortfall of about 500,000 tonnes of sand and gravel per year would be created. Much of this shortfall could be satisfied by other alternatives, but importation of concrete sand, and certain other high specification products into all areas of the Region would likely increase. Several sources could supply sand and gravel to the Region such as Caledon and Grey and Bruce Counties. But only four possible sources are considered economically viable:

1) Brantford / Paris
2) Cambridge
3) Aberfoyle
4) Dredged Sand from Erie, Pennsylvania

The Brantford / Paris area is the closest major source of supply of concrete sand and other sand and gravel products to the Region. An oversupply of local markets and high transportation costs to other markets within these areas have forced some of the pits here to shut down temporarily. Therefore the Brantford / Paris area is even more attractive for long-term supply committments.

The additional costs of bringing material into the Region from Brantford / Paris over the costs of transporting material from the Fonthill Kame would vary from about $1.02 per tonne at Smithville to $3.78 per tonne at Welland (see Table 6.2). It is found, that on a weighted basis over the entire Region, it would cost about $2.70 more per tonne to bring concrete sand from Brantford / Paris than it would to use Fonthill Kame sand (assuming that the price of concrete sand outside of the Region is about $1.50 per tonne less than Fonthill Kame material). These increased transportation costs mean that the delivered price of concrete sand from Brantford / Paris will be about 30 percent more than similar material from the Kame.

Additional trucking costs from Cambridge over the costs of transporting the material from Fonthill would be only marginally higher ($0.05 more per tonne) than the figures noted above when weighted over the entire Region. Additional costs of concrete sand from Aberfoyle would increase above these figures once again.

Concrete sand can also be imported, from Erie, Pennsylvania to the docking facilities at Port Colborne, across Lake Erie for a delivered price of $5.87 per tonne assuming that 2900 tonnes of sand can be delivered every 36 hours, 8 months a year. With an additional weighted average trucking cost throughout the Region of $0.90 per tonne plus truck loading and weighing costs estimated at $2.50 per tonne, the delivered price of Erie sand would be about $2.27 (see Table 6.2) more per tonne than material from Fonthill. It is clear, that from an economic standpoint, this may be the best importation option. However, it should be remembered that concrete sand from Erie, Pennsylvania does not have the high quality of the Brantford / Paris and other land-based areas.

Rail transportation was not evaluated in detail in this Study, because it was felt, that in recent years, railways in Ontario have raised their rates for transporting mineral aggregates to levels at which such transportation is no longer economically viable to most shippers. The railways' present philosophy is to quote rates marginally below those quoted by truckers. For that reason, the results of the analysis for the trucking of aggregates would not change materially, if rail tranportation were to be substituted for trucking in those few instances in which both the producer and user of concrete aggregates had railway sidings served by the same railway company.

Shipping of dredged materials from Erie, Pennsylvania to Port Colborne was found to be an economically viable option. Another possibility might involve the shipment of large quantities of aggregates to the Industrial Docks at Thorold.

8.8 Recycling, Substitution and New Technologies

As scarce, high quality reserves of sand and gravel in the Region gradually become more depleted, recycling, substitution and new technologies in building construction will become more significant.

Many different state-of-the-art technologies have been evaluated in Chapter 7.0 on the basis of the particular needs of the Niagara Region. From this work, it is clear that only three of these technologies could have a potential impact on the natural aggregate requirements in the Region. These include:

1) Recycled Asphalt Pavement
2) Waste Foundry Sand from St. Catharines
3) Pelletized Slag from Hamilton

Recycling of asphalt pavements has been slowly increasing since 1969 in Ontario. Currently, about 50 percent of new pavements being constructed by the Ontario Ministry of Transportation and Communications consist of Recycled Asphalt Pavement (RAP). However, on a province-wide basis, only about 10 percent of the aggregates in new asphalt pavements consist of RAP (specific figures for the Niagara Region are unavailable) because municipalities and their suppliers have generally resisted recycling practices in the past. Increased awareness of the advantages of recycling may begin to have an impact in future years. A number of problems are now associated with using RAP above 50 percent in new pavement mixes. For this reason, it is unlikely that recycling on a province-wide basis will increase much beyond this amount. In fact, it is anticipated that recycling will continue to increase from the present 10 percent to a maximum of about 30 percent by the year 2000 representing a savings of less than 1.8 percent (approximately 3.5 percent if the 50 percent maximum is assumed) of total cumulative aggregate requirements for the year 2000.

Waste foundry sand from the General Motors plant at St. Catharines is being generated at a rate of about 200,000 tonnes per year. Approximately half of this is now suitable for re-use. Most is sold as fill, but about 30,000 tonnes is being sold as fine aggregates for asphalt. It may be possible to use recycled foundry sand in concrete but the cost of cleaning the material and the environmental problems associated with the effluent which would be created make this option unattractive. Instead, it is anticipated that the trend will be towards increased recycling of this sand in the foundry process itself and none of this material will be available as an aggregate substitute in the future. Even if all of the foundry sand not being recycled now was used to replace natural aggregates, this would represent a reduction of only about 1.9 percent in the total cumulative demand for natural aggregates by the year 2000.

Pelletized slag is being produced by National Slag Limited in Hamilton at a rate of about 1.0 to 1.5 million tonnes per year. Approximately 60 to 70 percent of this material is currently being used for granular base material with most of the rest of it being used to produce a sulphate resistant cement. Technologically, pelletized slag could potentially replace the granular base materials being produced now by the Kame and act as a partial replacement for coarse aggregates in concrete. However, it is highly unlikely that pelletized slag will ever be used as a substitute for concrete sand since it is lighter in weight than other aggregates and crushed pelletized slag would have similar workability problems to those of crushed limestone in any case. Unless pelletized slag production is significantly increased in the future, it is highly unlikely that greater use of this material as an aggregate substitute will occur since virtually all of the slag being produced by National Slag is now being consumed. In addition, pelletized slag would have to directly compete with limestone aggregates. Therefore it may only be economically attractive to use pelletized slag in the northwestern part of the Region.

The use of geotextiles, advanced building techniques and better methods for preserving existing stuctures may all help to reduce the demand for new aggregates. It is anticipated that such techniques will reduce the overall aggregate demand requirements by about 3 percent.

In conclusion, it is anticipated that recycling, substitution and the application of new building technologies will likely reduce forecasted total cumulative aggregate requirements by about 7 percent by the year 2000. However, of all of the technologies studied in Chapter 7, only advanced building techniques is likely to have any significant impact on the demand for concrete fine aggregates. It is anticipated that techniques such as increased use of steel and high strength lightweight concrete will reduce the annual aggregate demand for concrete fine aggregates by about 5 percent by the year 2000 and about 10 percent by the year 2015.

8.9 Present Aggregate Supply Scenario

Table 8.1 shows the approximate quantities of aggregates presently being consumed in the Region from all sources. The small amount of sand and gravel being imported from Brantford / Cambridge has been neglected since it is difficult to determine where these aggregates are being used. Their effects on the results would be minimal in any case.

It is quite clear that the bulk of the material being produced by the Kame consists of granular base and subbase, coarse aggregates, concrete sand, asphalt sand and sand fill. Together these products represent approximately 98 percent of the total production on the Kame.

Table 8.2 shows several technically (and economically) feasible alternative sources for these aggregates if operations on the Fonthill Kame were phased out of production. Some of these have been discounted somewhat due to their economic or environmental costs.

PRESENT AGGREGATE SUPPLY / DEMAND IN THE NIAGARA REGION
(Based on average of 1981 - 1983)
(Tonnes)

SOURCE / PRODUCT TYPE	Fonthill Kame	Niagara Bar	Quarries	Other Land-based sources	Recycling & Substitution	Total
GROUP 1. (Granular Base & Sub-base)	189,000	---	544,000	---	---	733,000
GROUP 2. (Coarse Aggregate)	40,000	---	442,000	---	1,000 (RAP)*	483,000
GROUP 3. (Fine Aggregate)	278,000	30,000	74,000	---	31,000	413,000
Concrete Sand	235,000	5,000	---	---	---	240,000
Asphalt Sand	40,000	---	24,000	---	30,000 (Foundry Sand) 1,000 (RAP)*	95,000
Ice Control	3,000	---	50,000	---	---	53,000
Others	---	25,000	---	---	---	25,000
GROUP 4. (Clear Aggregate)	7,000	---	1,000,000	---	---	1,007,000
GROUP 5. (Others)	60,000	---	306,000	37,000	---	403,000
Sand Fill	60,000	---	---	37,000	---	97,000
Screenings	---	---	249,000***	---	---	249,000
Other	---	---	57,000	---	---	57,000
	574,000	42,000 **	2,366,000 (Excludes approx. 1,000,000 tonnes currently being exported)	37,000	32,000	3,039,000

* RAP - Recycled Asphaltic Pavement

** Excludes approximately 40,000 tonnes shipped to Hamilton

*** Includes as estimated 70,000 tonnes which are used as fine Aggregates in Concrete

Table 8.1

POTENTIAL SOURCES OF AGGREGATE REPLACEMENT FOR THE FONTHILL KAME

PRODUCT TYPE	Quarries	Other Land Based Sources	Importation of Sand and Gravel	Recycling and Substitution	Materials (Niagara Bar & Lake Erie)
GROUP 1.	X		X	Pelletized Slag*-(P)	
GROUP 2.	X		X	Pelletized Slag*-(P) Steel Slag**-(P)	
GROUP 3.					
a) Concrete Sand	X-(P)	X	X	Foundry Sand****-(P)	X
b) Asphalt Sand	X	X	X	Pelletized Slag*-(P) Foundry Sand Steel Slag***(P)	X
c) Ice Control	X	X	X		X
GROUP 4.					
Clear Aggregate	X		X	Pelletized Slag* Steel Slag***	
OTHERS					
Fill	X	X	X	Pelletized Slag* Steel Slag**	X
Screenings	X				

Notes:

(P) Partial Replacement

* National Slag Limited of Hamilton

** Steel Slag from Atlas Steel in Welland and Stelco/ Dofasco in Hamilton

*** Steel Slag from Stelco/ Dofasco in Hamilton only

**** Not economically attractive in near to middle term

Table 8.2

8.10 Alternate Sources of Aggregate Products Presently Being Produced on the Fonthill Kame

8.10.1 Products Other Than Concrete Sand

The Fonthill Kame annually produces about 236,000 tonnes of granular base and subbase, clear aggregates and coarse aggregates at present. Nearly all of this material could be replaced by quarried limestone.

Quarries could also replace the winter sand currently being produced by the Kame. In fact, the Ministry of Transportation and Communications has suggested that, as long as the material is double-washed to limit fines, winter sand from quarries can completely replace natural sand in the Region.

The existing quarries have produced substantially greater quantities of products in the past than at present. Increasing their production to make up shortfalls of the products mentioned in the first paragraph should present no real problem. In addition, pelletized slag could also provide some additional material at the western fringes of the Region.

The only problem that would be created by replacing these products with quarried material or slag would be the increased transportation costs of bringing this material to the central part of the Region as there is no potential quarry development in this area. However, the quantities of materials which would be brought here would be relatively small and this should not be a major concern.

Approximately 60,000 tonnes of sand fill is currently being produced by the Kame. This could be replaced by natural aggregates from other land-based sources in the area, dredged materials from the Niagara Bar or Lake Erie (at much higher cost) and quarries. The alternative sources of natural aggregates would cause higher overall transportation costs due to the fact that they are unevenly distributed in the Region while the Fonthill Kame is a centrally-located source.

The Kame annually produces about 40,000 tonnes of asphalt sand which represents about 42 percent of the asphalt fine aggregates used in the Region. Increased recycling coupled with higher use of quarry screenings, dredged sand and recycled foundry sand could potentially eliminate the need for any asphalt sand from the Kame. The Ministry of Transportation and Communications has suggested that the generally high cost of asphalt sand produced from the Kame has already resulted in nearly a complete replacement of asphalt sand with recycled foundry sand in a large number of their construction contracts (Katona, Personal Communication).

8.10.2 Concrete Sand

Concrete sand is the only material currently being produced by the Kame which cannot easily be replaced by any of the alternatives. From the aggregate demand study in Chapter 2.0, it was found that total demand for concrete fine aggregates required by the end of the year 2000 will be about 8.1 million tonnes (Table 2.8).

Other land-based sources in the Region are not likely to provide any significant amounts of concrete sand. Foundry sand is not likely to be used as it would be too expensive to process and it would either be recycled or used to replace the shortfall in asphalt sand in any case. Therefore, there are only three possible alternative sources available for concrete sand:

1) Dredged sand from the Niagara Bar

2) Screenings or manufactured sand from quarries

3) Importation from the Brantford/Paris or Cambridge areas or dredged sand from Erie, Pennsylvania

Most of the users of concrete sand felt that large-scale importation of this material into the Region would be the most reasonable alternative. Importing concrete sand from Brantford/Paris or Erie, Pennsylvania would respectively cost $2.70 and $2.30 more per tonne, on average, throughout the Region as compared to the FOB price at Fonthill.

Greater use of screenings and/or manufactured sand from quarries as well as dredged sand from the Niagara Bar are considered in more detail below.

8.10.2.1 Screenings and Manufactured Sand

It was shown in Chapter 4.0 that a good quality concrete of sufficient durability and strength can be made using only quarried products. Such concrete is now being used in areas such as South Africa, Europe, Australia and a few places in the United States (such as Eastern Tennesee) where conventional sources are limited.

As far as is known, there is no precedent for the complete replacement of concrete sand with manufactured sand in Portland cement concrete anywhere in Central Canada, although partial replacement in ready-mix and its use in bricks and blocks does occur. For example, Spratt sand and gravel near Ottawa is producing a manufactured sand for use in the production of concrete blocks and Miron in Quebec is producing a manufactured sand for partial replacement in ready-mix.

Manufactured sand can be produced at a cost which is competitive with the cost of importing natural concrete sand from outside the Region. However, the major problem with concrete made totally from quarried products has been one of workability. To produce a concrete of suitable workability totally out of crushed limestone or dolostone would require a premium of $4.00 per tonne compared to the cost of importing from Brantford/Paris. This is due to the additional cement and the additives or air-entrainment required to increase concrete workability.

However, as the price of concrete sand from Fonthill increases, greater substitution of quarried fine aggregates in concrete is likely to occur. If it is assumed that substitution of quarry products from the present level of 20 percent will increase to about 30 percent by the end of this century (even if the Kame continues to produce concrete sand) then the total fine concrete aggregates required will be about 7.2 million tonnes (or a reduction of about 1 million tonnes from earlier predicted levels) (see Table 8.3) by the year 2000. Such substitution could be increased to about 40 percent with no real workability problems.

It is therefore anticipated that if the Fonthill Kame is gradually phased out, quarried fine aggregates could partially replace concrete sand to a maximum of 40 percent at a cost which could be competitive with importation of natural sand from Brantford/Paris or Cambridge. Workability problems would increase above a 40 percent mix ratio to the point where the cost of overcoming them may be prohibitive and importation of natural sand or the use of dredged sand may be more reasonable options. The maximum extent to which substitution by quarried materials can practically occur in the Region will therefore be highly dependent on the prevailing economic climate and technological factors.

8.10.2.2 Dredged Sand

The use of dredged sand from the Niagara Bar may represent the best substitute for some types of sand products presently being produced by the Kame. It is clear from information presented in Chapter 3.0 that the dredging industry could substantially increase total production from the Niagara Bar (See Figure 8.1). With existing boat facilities, the production of the present operation can be doubled with a double shift. Further increases would require additional boats. A market demand three times that of the present and a minimum 10 year lease are considered essential by the present operators to justify the purchase and conversion of new or used boats.

A limiting factor, however, may be encountered in the available quantity of concrete sand made totally from dredged materials. It is estimated that if, through selective mixing, the material available from the Niagara Bar is used to replace the full production of concrete sand from Fonthill, plus what is produced already from the Bar (approximately 76,000 tonnes), this estimated resource will last about 25 years.

On the other hand, if the fine aggregates on the Bar currently only suitable for masonry and plaster works were mixed with a coarse manufactured sand from quarries, there is no foreseeable limit for future concrete fine aggregate production.

The percentage of deleterious materials such as chert will have to be reduced to within specification limits before concrete fine aggregates using dredged sand will be generally accepted by the major users. Proper mixing of the two aggregate types would also reduce the overall percentage of chert and enhance the quality of the material. However, it should be noted that the behaviour and

REDUCED DEMAND FORECAST FOR CONCRETE FINE AGGREGATES
(000's of Tonnes)

Annual Demand for Concrete Fine Aggregates (Table 2.2 - Column 2)	Reduced Annual Demand for Concrete Fine Aggregates	Reduced Cumulative Demand for Concrete Fine Aggregates
320	320	320
317	314	630
404	397	1,030
410	400	1,430
402	389	1,820
415	398	2,220
427	406	2,620
440	416	3,040
454	424	3,460
468	434	3,900
482	443	4,340
496	452	4,790
510	460	5,250
525	470	5,720
541	480	6,200
558	490	6,690
574	499	7,190

Table 8.3

SUMMARY OF PRESENT DAY DREDGING OPERATION AND PRODUCTION FROM THE NIAGARA BAR

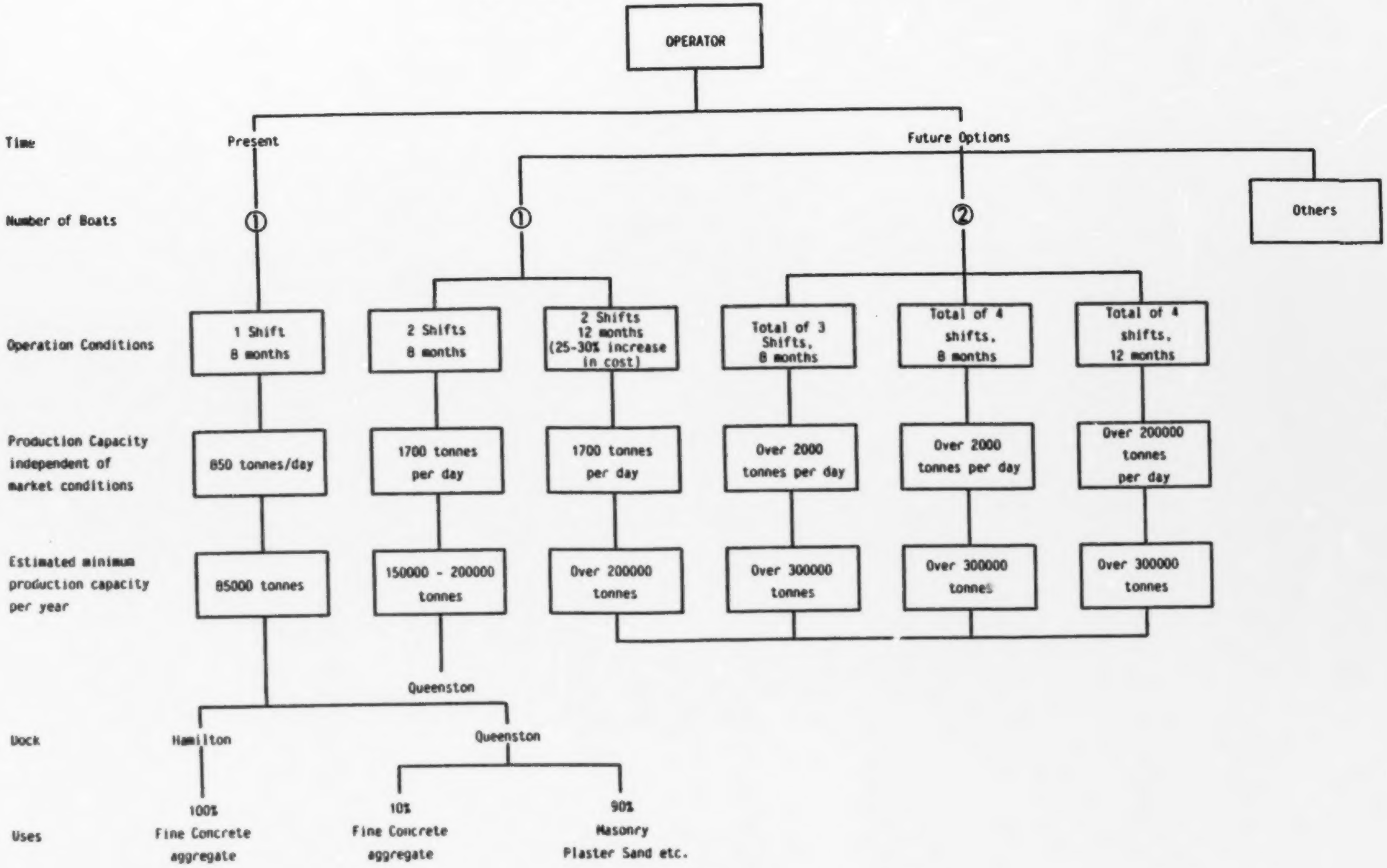

OPERATOR
Time
Present
Future Options
Number of Boats
①
①
②
Others
Operation Conditions
1 Shift 8 months
2 Shifts 8 months
2 Shifts 12 months (25-30% increase in cost)
Total of 3 Shifts, 8 months
Total of 4 shifts, 8 months
Total of 4 shifts, 12 months
Production Capacity independent of market conditions
850 tonnes/day
1700 tonnes per day
1700 tonnes per day
Over 2000 tonnes per day
Over 2000 tonnes per day
Over 200000 tonnes per day
Estimated minimum production capacity per year
85000 tonnes
150000 - 200000 tonnes
Over 200000 tonnes
Over 300000 tonnes
Over 300000 tonnes
Over 300000 tonnes
Queenston
Dock
Hamilton
Queenston
Uses
100% Fine Concrete aggregate
10% Fine Concrete aggregate
90% Masonry Plaster Sand etc.

Figure 8.1

strength of concrete made from a mix of this nature has never been satisfactorily investigated and this should be studied in the future (See Section 8.11 - Future Work).

The dredging operations apparently have strong advantage over land-based pit operations at a time when the fuel costs are high and any time when the material can be transported by boat directly to major users, such as to Red-D-Mix of Hamilton from the Niagara Bar. One of the difficulties the dredging product operation is encountering in providing the user with a consistent quality product is the lack of a stockpiling area and the mixing capability that land-based pits have. Facilities with the capability of blending materials to achieve a consistent high quality product will be one of the main pre-requisites for any future, substantial increases in production from the Bar.

8.10.2.3 Supply / Demand Scenarios

Alternative supplies of concrete fine aggregates to the Region will be a major issue if the Fonthill Kame is gradually phased out. Several different supply / demand scenarios for these aggregates can be considered, some of which, are presented in this section.

The yearly cumulative demand for concrete fine aggregates up to the year 2000 has been presented in Table 2.8. If this is extrapolated to the year 2015 and it is assumed that recycling and substitution will reduce this projected yearly demand by 5 percent by the year 2000 and 10 percent by the year 2015, then the adjusted cumulative demand for concrete fine aggregates may be represented by the demand curve shown in Figure 8.2.

In any supply / demand scenario, the Niagara Bar will likely figure prominently since it is the only major source of concrete sand in the Region outside of the Fonthill Kame. If the coarse and fine materials in the Bar are mixed in a 1 to 2 proportion, then the potential reserves of concrete sand from dredged materials is estimated to be about 6.9 million tonnes provided the material has been beneficiated to reduce the chert and other deleterious materials content to such an extent as to make it generally acceptable.

However, if the finer fractions are mixed with coarser sands from quarries, the Fonthill Kame or imported material, then the reserves can be considered inexhaustable at least for the foreseeable future (up to the year 2015).

Figure 8.2 shows the cumulative production of concrete sand from the Niagara Bar for the four cases presented below:

Curve No.	
I	Production of concrete sand from the Bar being used in the Niagara Region will continue at present rates of approximately 5,000 tonnes per year.

LEGEND

CUMULATIVE PRODUCTION OF CONCRETE FINE AGGREGATES FROM THE NIAGARA BAR AND QUARRIES.

I	Present Regional production of Concrete Sand from the Niagara Bar consumed in the Region (5000 tonnes per year).
II	Maximum single shift production of Concrete Sand from the Niagara Bar (45,000 tonnes per year excluding material brought to Hamilton).
III	Maximum double shift production of Concrete Sand from the Niagara Bar (140,000 tonnes per year).
IV	Maximum triple shift production of Concrete Sand from the Niagara Bar (260,000 tonnes per year).
V	Production from quarries represents 20% of the total annual demand.
VI	Production from quarries if manufactured Sand industry is developed. The production of Concrete fine aggregates from quarries will increase from the current 20% to 40% of the annual demand by the year 2000 and remains constant thereafter.

Legend for Figure 8.2 which is shown on the opposite page.

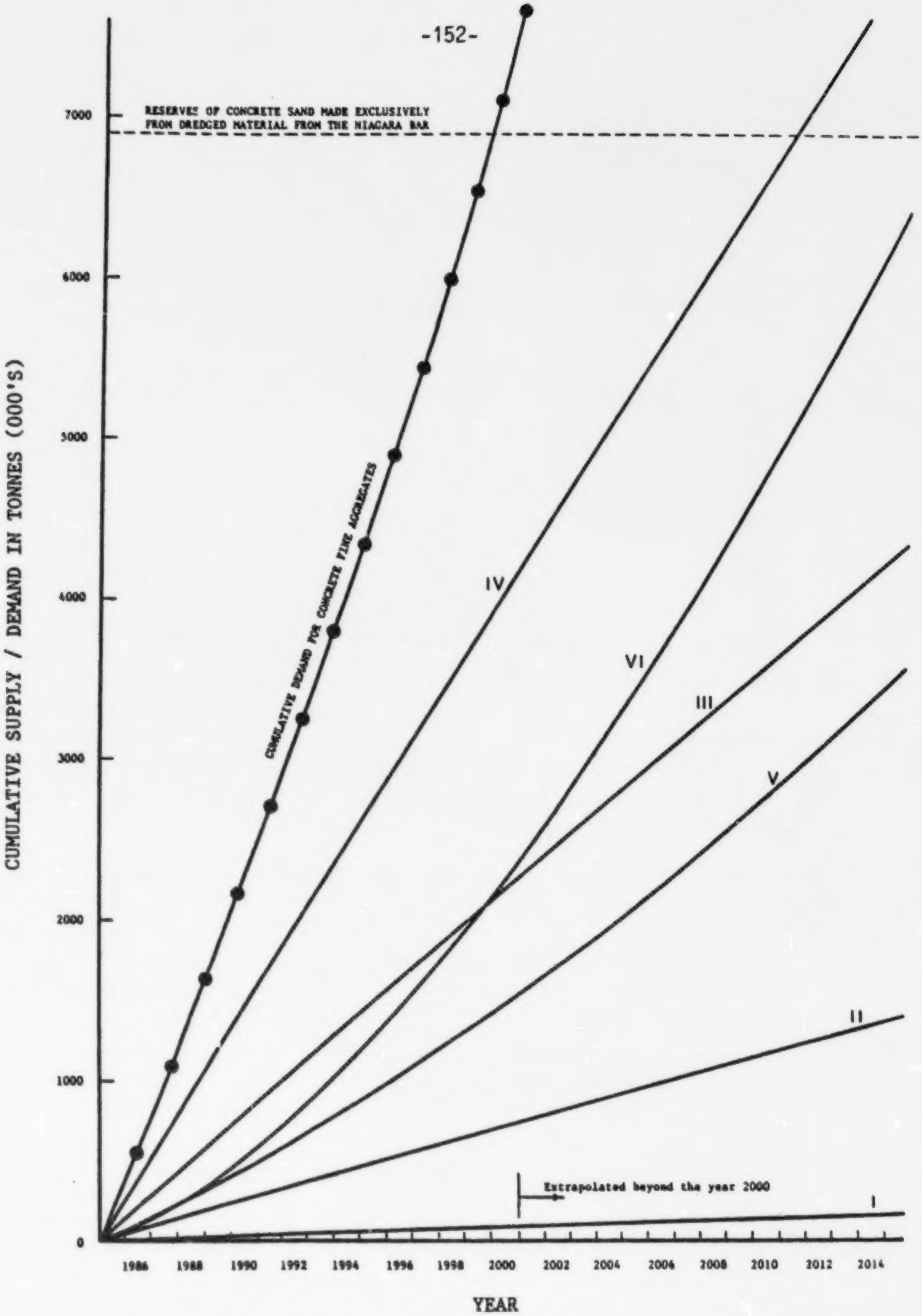


Figure 8.2 - Cumulative Demand for Concrete Fine Aggregates and Several Different Supply Scenarios from the Niagara Bar and Quarries. (See opposite page for legend).

II All of present capacity of the one operator (excluding the material being shipped to Hamilton) or 45,000 tonnes per year will be used to produce concrete sand used in the Niagara Region.

III A double shift capacity of 140,000 tonnes per year from the one operator will be entirely devoted to the production of concrete sand used in the Region.

IV A triple shift capacity of 260,000 tonnes per year from the one operator will be entirely devoted to the production of concrete sand used in the Region.

If concrete sand is produced using only dredged materials, then the reserves of these materials will be exhausted in the forseeable future (before 2015) only if a triple shift is considered (ie. greater than 260,000 tonnes per year) and if no mixing of finer fractions from the Bar with coarser materials from elsewhere occurs.

Quarries currently provide about 20 percent of the fine aggregates used in concrete. Curve V shown in Figure 8.2 shows the cumulative future supply of concrete fine aggregates from quarries if the current trend continues. However, if a manufactured sand industry is developed, then it is assumed that the percentage of concrete fine aggregates represented by quarries will increase from the current 20 percent to about 40 percent (maximum amount at which workability is assumed not to be a problem) by the year 2000 and remain constant thereafter. The cumulative supply of concrete fine aggregates in this case is shown by curve VI in Figure 8.2.

The difference between the cumulative supply and demand curves shown in Figure 8.2 represents the shortfall in demand which must be made up through the use of Fonthill Kame material or through importation from outside of the Region.

To determine the exhaustion date of the Fonthill Kame, it is assumed that the 2 million tonnes of aggregates remaining in existing licenses on the Fonthill Kame as well as the 6.2 million and 1 million tonnes in the expansions of the T.C.G. and Steed and Evans properties respectively will be available for extraction. If it is also assumed that approximately 60 percent of the aggregates in the Kame are suitable for concrete sand, then the reserves of concrete sand in the Kame are estimated to be about 5.52 million tonnes.

In Figure 8.3, curves 1-5 show the concrete sand requirements (shortfall in demand) using five different scenarios. Maximum use of concrete fine aggregates from quarries and the Niagara Bar is assumed first. The additional concrete sand required to make up the shortfall in demand shown by these curves could come from either the Fonthill Kame or through importation of material from outside of the Region.

Curve 1 represents an extension of the existing scenario in which the Niagara Bar provides about 5,000 tonnes per year of concrete sand (Line I) and quarries will continue to provide about 20 percent of the concrete fine aggregates used in the Region. If no importation occurs, then the Kame will be exhausted by about the year 2001.

Curve 2 is similar but assumes that all of the capacity for a single shift (45,000 tonnes per year excluding material being transported to Hamilton) is used to produce concrete sand for the Region.

Curve 3 assumes that a double shift of production of concrete sand from the Bar (140,000 tonnes per year) will be provided to the Region in addition to the 20 percent of demand provided by quarries.

If a double shift of concrete sand production on the Bar is coupled with the introduction of a manufactured sand industry, then the Fonthill Kame might be extended by another five years (Curve 4).

Finally, Curve 5 shows the cumulative demand for concrete sand assuming that a triple shift is used to produce concrete sand from the Niagara Bar and a manufactured sand industry is developed. In this case, the reserves of concrete sand from the Bar would be exhausted before the Fonthill Kame (assuming that no mixing of Bar sand with other materials occurs and importation is not considered).

These scenarios only show the shortfall in cumulative demand for concrete sand. This shortfall can be made up through use of the Fonthill Kame or through importation. It is quite clear that the dates of exhaustion for the Kame would be altered remarkably if imported material was used to replace some of the Fonthill Kame material.

8.11 Observations and Recommendations

Based on the work of this Study, a number of observations and recommendations can be made:

8.11.1 Observations

1) There is a need to improve the overall management of all presently available aggregate resources to obtain the maximum quantity of concrete sand. It is unlikely that restrictions would be placed on the type of products sold from a pit in order to achieve wise management unless these pits were acquired specifically for that purpose.

LEGEND

CUMULATIVE SHORTFALL FOR ALTERNATIVE CONCRETE FINE AGGREGATE SUPPLY SCENARIOS

1 Extension of the existing scenario- 5,000 tonnes per year produced by the Niagara Bar (I) and 20% of the demand is satisfied by quarries.

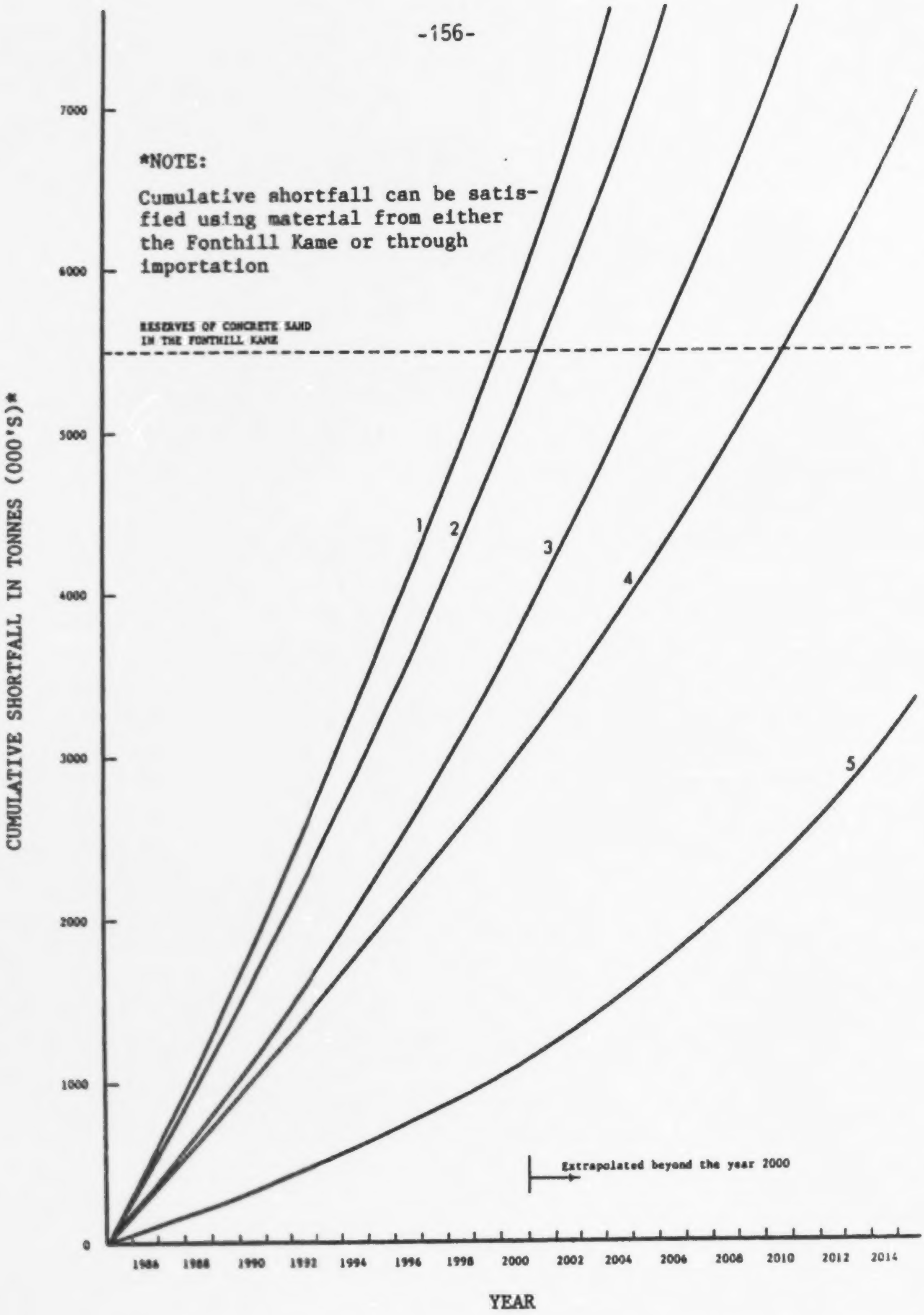
2 Similar to 1 but 45,000 tonnes per year (single shift - II) is produced from the Niagara Bar.

3 Similar to 1 but 140,000 tonnes per year (double shift - III) is produced from the Niagara Bar.

4 Similar to 3 but a Manufactured Sand industry is introduced in 1985 increasing the fine aggregate from quarries to a maximum of 40% by the year 2000.

5 Similar to 4 but 260,000 tonnes per year (triple shift - IV) is produced from the Niagara Bar.

Legend for Figure 8.3 which is shown on the opposite page



*NOTE:

Cumulative shortfall can be satisfied using material from either the Fonthill Kame or through importation

Figure 8.3 - Cumulative Shortfall in Demand for Concrete Fine Aggregates. (See opposite page for legend).

2) More research is required in evaluating the environmental affects of expanding the existing dredging operation on the Niagara Bar.

3) More research is required into the effects on the strength and workability of concrete made with a mixture of manufactured sand (or screenings) and dredged materials from the Niagara Bar (See Section 8.12.1).

4) Both quarry operators and concrete producers should become more aware of the use of manufactured sand (and screenings) in Portland cement concrete since it is inevitable that greater use will be made of this material if the Fonthill Kame can no longer provide concrete sand. It is hoped that this would lead to the establishment of a manufactured sand industry in the Region.

8.11.2 Recommendations

1) It is evident that complete replacement of all products currently being produced by the Fonthill Kame is technically feasible using some or all of the various alternatives studied. However the alternatives to Kame concrete sand which are presently available will be more expensive (at least 30 percent more) to ready-mix manufacturers and other direct consumers of concrete fine aggregates. The impact on housing and construction costs, however, will be minimal. More extensively beneficiated dredged sand from the Niagara Bar or the mixing of dredged Bar sand with concrete fine aggregates from quarries may not be as expensive as importation. However, a detailed testing program and economic analysis should be carried out on these options before any direct comparisons are made.

   The Kame is a very significant tender-fruit growing area. Such areas are scarce and local citizens and environmentalists would prefer them to be used for that purpose.

   If it is decided to convey the Kame to tender-fruit growing and other environmentally more acceptable uses, the transition from present to future use should be made over a period of time. Such a phasing out period is necessary not only to allow orderly winding up of the concrete operations but also to permit development and deployment of the various alternative resources in the Region to meet the expected aggregate demands of the future.

2) It is recommended that greater incentives should be provided to allow expansion of the dredging operations on the Niagara Bar. This might involve a change in regulations which would allow the establishment of long term leases and/or a reduction in royalty payments. This would not only result in an increase in the quantities being produced but it would also provide the dredger with the needed impetus to establish shore facilities as well as mixing and benefication equipment so that he can continuously produce a high quality concrete sand.

8.12 Recommended Future Work

8.12.1 Research Programs

Both the workability of the concrete produced and the amount of additional cement required when manufactured sand partially replaces concrete sand is heavily dependent on the type of crushing equipment employed and the kind of limestone being used. It is therefore recommended that a reasonable quantity of limestone from a centrally-located quarry in the Region (ie. central to the major producers of ready-mix) be sent to producers of manufactured sand (such as Miron in Montreal or Spratt near Ottawa) who are now using various state-of-the-art crushing and screening equipment. The material should be crushed and graded to conform to CSA standards. Analyses of particle size and shape should be carried out. This should be followed by a modest testing program to evaluate the strength and workability (including pumpability), slump, water-cement ratio etc. of concrete mixes using various proportions of natural sand and manufactured sand. The results can then be used to determine the maximum quantity of manufactured sand which can be practically (and economically) used in Portland cement concrete mixes.

Research should also be carried out on mixes of manufactured sand and dredged fine sand from the Niagara Bar. The strength and behavioural characteristics of such concrete mixes is not presently known.

8.12.2 Niagara Bar Quantity Estimate

Many of the estimates and concepts concerning the materials available in the Niagara Bar are based on direct information from dredging operators and one set of samples obtained from a nearshore survey by the National Water Research Institute. While the dredging operators can provide good data on their area of operation, the small and widely distributed samples can only provide a very preliminary indication of the quality and quantity of the material in the remainder of the deposits. Therefore, the estimates of the reserves of concrete sand from the Niagara Bar are only approximate ones. They will require confirmation through specifically designed sampling and testing programs. Any such program should also include a better assessment of the impact that a significant increase in dredging would have on the environment and eco-system in the Niagara Bar area and vicinity.

8.12.3 Additional Areas of Study

Future work should address a number of issues in more detail including analyses and comparison of material and processing costs and long distance transportation by rail and ship. In addition, the impact of various alternatives on the industry and their direct affect on the consumer in terms of end products (houses, roads etc.) should be studied. Also, a major environmental impact study of each of the alternatives should be undertaken.

Future work should be done by consultants in association with various Ontario universities such as Brock, Guelph and Toronto.

8.13 Conclusions

1) This Study has shown that it is feasible to satisfy the future (to the year 2000 +) aggregate demands of the Niagara Region from sources other than the Fonthill Kame.

2) The alternative sources of significance consist of dredged materials from the Niagara Bar and crushed stone and manufactured sand from quarries. Further research is required on the Niagara Bar deposits to establish more positively their potential for use as concrete sand, both in terms of quality and quantity. However, the supply of quarried aggregates is virtually inexhaustible.

3) The realization of the full potential of quarried fine aggregates will take some time, since experience would be required to produce a manufactured concrete sand of acceptable quality. Further research is also required to determine the quality and acceptability of concrete made with blended fine aggregates from the Niagara Bar and quarries (manufactured sand and/or screenings)

4) Imported materials into the Niagara Region can meet short term demands if the Fonthill operations are phased out faster than the development of the Niagara Bar potential and the establishment of a viable manufactured sand industry in the Region. However, a cost premium will be involved, whose economic impacts will be directly related to the duration of the phasing out program.

9.0 REFERENCES

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APPENDIX I

COPY OF REPORT DPD 1739, File QU/RE.am-14

DPD 1739 as amended by
Council June 21, 1984

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Report to: Mr. Bergenstein, Chairman and Members
of the Planning and Development Committee

Mr. Campbell, Chairman and Members
of Regional Council

Councillors:

Alternative Sources of Sand and Gravel: The Study Outline

Overview

Over the past several years, the Fonthill Kame has been experiencing increasing land use conflicts with applications for three new or expanded pits. The Kame area is part of a provincially and nationally significant tender fruit growing area. In the Niagara Region, it is the major existing land-based source for sand and gravel, about 90%. As well, the Kame area is important for its environmental, scenic, and recreation features. Consequently, what are the opportunities for reducing these conflicts through the use of alternative sources of sand and gravel to replace all or some of the material extracted from the Fonthill Kame? To bring together the answers to this question is this study's purpose. These answers then will affect land use decisions.

Seven tasks combine to form the alternative sources study which will benefit from information obtained from the 1980-1981 work on the supply and demand for sand and gravel. Funding of $20,000 has been assembled over three years by the Planning Committee including $5,000 in the 1984 budget. The Town of Pelham has proposed a contribution of $5,000. In addition, Provincial funding will continue to be sought where possible.

The seven tasks are outlined below and described more fully in the appendix. Consultants will be requested to submit proposals to undertake one or more of the tasks.

Seven Tasks

The purpose of this study is:

> To examine the future feasibility of replacing all or some of Niagara's sand and gravel needs

now derived from the Fonthill Kame with alternative sources.

To achieve this purpose, the study is divided into the following seven tasks:

Task 1 - Review and Update of the Demand for Sand and Gravel in Niagara

To review the demand estimates made in 1980-1981 and to update the future demand for sand and gravel. Considerations will be given to the types of products required, amounts, and sources of demand.

Task 2 - Dredged Material

To document the reserves of sand and gravel in the Niagara Bar and its uses, and to assess its future potential use as well as possible sources from Lake Erie.

Task 3 - Manufactured Sand and Gravel from Quarries

To examine the existing literature, state of the art technology and existing stone resources of Niagara to determine the potential of manufactured sand and gravel from quarries to replace existing sand and gravel products produced on the Kame.

Task 4 - Other Land Based Pits

To assess the potential of other land based sites of sand and gravel in Niagara to replace the materials from the Fonthill Kame. This task will be carried out by Regional Planning staff with information from the Ministry of Natural Resources.

Task 5 - Imported Material

To provide an overview of the economic feasibility and implications of importing sand and gravel supplies from outside the Niagara Region considering various transportation systems and the likely impact on construction costs.

Task 6 - Recycling, Substitution and New Technologies

To examine recent and possible future trends and technologies to determine the potential of various conservation measures such as recycling and substitution in reducing future demand for sand and gravel supplies from the Fonthill Kame.

Task 7 - Synthesis and Conclusions

To synthesize the results and conclusions contained in Tasks 1 to 6 and make recommendations regarding the feasibility of substituting alternative sources of supply for those on the Fonthill Kame.

The detailed terms of reference also refer to a study of environmental and cultural costs associated with sand and gravel operations on the Fonthill Kame. The Provincial staff have indicated that this topic should form an important component in the overall study. It is proposed that this topic be examined as phase 2 of the overall study and provided full Provincial funding is made available.

Consultants

The following is a list of some possible consultants who might be able and willing to carry out one or more tasks listed in the terms of reference.

- Ecological Services for Planning (Guelph)
- Dalhousie Aggregates (St. Catharines)
- Trow Group, Consulting Engineers (Toronto)
- Victor and Burrell, Socio-Economic Consultants (Toronto)
- Proctor and Redfern Ltd. (St. Catharines)
- Acres Consulting Services Ltd. (Niagara Falls)
- Emrik Suichies, Planning Consultant
- J. Conlon Engineering (Welland)

It is proposed that staff contact and interview the consultant or consultants who it is thought can best carry out the required work. Apart from the expertise of the individuals carrying out the study, a prime prerequisite will be the perceived independence of the successful consulting firm. For obvious reasons, the selected consultants should not be associated with any existing operators on the Kame or predisposed to a particular point of view. While it would be desirable from the point of view of continuity to award the study to a single consultant, more than one consultant may be selected depending on the specialized nature of individual tasks and the expertise of the various consulting firms.

Scope of the Study

It is anticipated that the study will take approximately 2 to 3 months to complete. Much of the background information is already available in scattered sources. Very little if any of the work and data collection will require original research.

It is important that the consultants work closely with and report regularly to Regional Planning staff. It is important that any consultant(s) selected appreciate fully the policy context of the study. Also, from a practical standpoint, Regional staff have some of the background data necessary to complete the study. It will also be necessary for the consultants to contact Ministry of Natural Resources staff for background data and sources of information.

Recommendations

1. That the study of alternative sources of sand and gravel supply proceed as set out in this report.
2. That staff with assistance from a representative of the Town of Pelham be authorized to interview and select a qualified consultant or consultants to carry out the Study for the consideration and final approval of the Planning and Development Committee and Regional Council.
3. That the Planning Committee and the Town of Pelham be kept informed on a regular basis of progress on the Study.

Prepared by

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Ken Forgeron

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Planners

Corwin T. Cambray

Corwin T. Cambray
Manager, Policy Planning

Respectfully submitted

Alan Veale

Alan Veale
Director of Planning

DS/KJF/jt

Study of Alternative Sources of Sand and Gravel to those on the Fonthill Kame

Appendix

Detailed Terms of Reference

Purpose: To examine the future feasibility of replacing all or some of Niagara's sand and gravel needs derived from the Fonthill Kame with alternative sources.

Task 1

Demand for Sand and Gravel

a) identify the type and amount of sand and gravel products being produced from the Fonthill Kame.

b) develop a scenario of the likely future requirements for sand and gravel in Niagara based on a review and appraisal of the results and conclusions contained in the demand forecasts carried out in the 1981 Regional Niagara Sand and Gravel Study. Of particular interest is the requirement for sand and gravel for concrete production.

update the findings contained in the 1981 study if necessary.

Note:

This task forms an important starting point for many of the possible conclusions in the following tasks and should be carried out prior to beginning any subsequent tasks outlined here.

Task 2

Dredged Material

a) through the use of existing sources and information from operators, provincial, federal and Regional staff, map the location and estimate the size and quality of existing reserves of sand and gravel material in the Niagara Bar. The suitability of dredged material for concrete production should be assessed.

b) examine the history of dredging in the Niagara Bar, including the tabulation of past and present production figures and the range of products historically produced from dredged sand and gravel materials, citing examples of their use in Niagara, South Central Ontario and New York State.

c) prepare an overview of the constraints and opportunities operating in the dredging industry including an examination of production costs - (i.e. equipment, labour transportation); institutional factors - (i.e. MNR permits, federal permits, MTC material specifications); quality of material; new technology; existing producers; docking facilities, etc.

d) develop a reasoned assessment of the capability of the dredging industry to increase production and indicating the likely share of the market assuming:

(1) continuation of competition from existing land based pits on the Fonthill Kame,

(2) the gradual phasing out and eventual end of land based sourcing of sand and gravel supplies particularly of the construction grade materials including concrete sand.

e) assess, by way of an overview, potential environmental concerns related to continued dredging in the Niagara Bar.

f) examine the ability of other dreding operations other than on the Niagara Bar (for example Erie Sand and Gravel) to meet some of the sand and gravel needs of Niagara.

Task 3

Manufactured Sand and Gravel from Quarries

a) examine existing literature and consult with existing producers, operators and other officials in the industry to determine the potential range of uses and products obtainable from manufactured sand and gravel materials.

b) examine several examples of manufactured sand and gravel operations and determine what if any problems or potentials exist which are relevant to the Niagara situation.

c) examine state of the art technology in the manufactured materials industry to determine factors which might affect the types, quality and costs of material produced in the future.

d) assess the suitability of stone resources of Niagara to support manufactured sand production. The assessment of stone resources other than those in licensed areas should consider uses on them in considering availability.

e) cite examples of actual users of manufactured sand materials in Niagara or elsewhere.

f) identify what producers manufactured sand and gravel may be able to replace from existing sand and gravel products produced on the Fonthill Kame and, in particular, concrete sand.

Task 4

Other Land Base Pits

a) list locations other than the Fonthill Kame in Niagara from which sand and gravel can be obtained.

b) indicate the limitations and constraints including agricultural land capability to the development of thesp sources and the range of products possible.

Note:

Task 4 can be done by Regional Planning staff in co-operation with District staff of the Ministry of Natural Resources and using existing sources of information.

Task 5

Material Imported from Outside Niagara

a) indicate the sources of sand and gravel replacement products including concrete sand located outside of Niagara and assess their ability to meet Niagara's present and projected future needs.

b) examine the costs of importing concrete sand and other replacement products into Niagara using various transportation systems (rail, truck, ship). The potential of the Welland Canal to ship products should be examined.

c) compare the likely costs of importing sand and gravel with the costs of existing materials from the Fonthill Kame and assess what if any implications there will be on existing construction costs.

Task 6

Recycling, Substitution and New Technologies

a) indicate to what extent recycling and substitution is being done, how and why?

b) examine the factors that may lead to decisions to recycle or substitute.

c) indicate to what extent these practices are likely to increase or decrease and why?

d) examine state of new technologies in construction which may reduce the overall demand for aggregate materials.

e) suggest what proportion of total demand for sand and gravel including concrete sand, in Niagara might reasonably be expected to be accounted for in the future through recycling, substitution and new technologies.

Task 7

Synthesis and Conclusions

a) synthesize the results and conclusions contained in previous tasks 1 to 6 and make recommendations regarding the feasibility of substituting alternative sources of supply by product type for those on the Fonthill Kame. Examine the affect on the land needs for sand and gravel extraction from the Kame if alternatives are found for only some of the product types.

Task 8

Environmental and Cultural Factors

This particular project was considered important by the Province in its overall consideration of funding for the study. The development of detailed terms of reference for this portion of the study should be based on input and advice from the Province and its carrying out would be conditional on the receipt of necessary funds from the Province.

APPENDIX II

AGGREGATE SPECIFICATIONS

NOTE: $1\ \mu = 1$ micrometre $= \frac{1}{1000}$ millimetre (mm)

GROUP 1:
GRANULAR BASE AND SUBBASE

1.1 Granular Base and Subbase material may be defined as a dense graded non-cohesive mineral aggregate, normally specified and identified in terms of the nominal size of the material and processed by crushing and by screening or blending suitably graded materials to conform to the gradation requirements and standards of quality as outlined in 1.3 and 1.4 respectively. In the case of Granular "B" and Granular "C", processing may not be necessary to meet these requirements.

1.2 Source material may be: (i) quarried rock, (ii) sand and gravel deposits, (iii) iron, steel or nickel slags.

1.3 **AGGREGATE GRADATION LIMITS**

Sieve Size	PERCENT PASSING					
			*16-37.5 mm Crushed	*16 mm Crushed		9.5 mm Crushed
	Granular "C"	*Granular "B"	Granular "A"	Type "A"	Type "B"	Granular "D"
150 mm	100					
106 mm		100				
53 mm						
37.5 mm			100			
26.5 mm	50-100					
22.4 mm		57-100				
19 mm						
16 mm			62-100	100	100	
13.2 mm				75-95	75-95	
9.5 mm			48-73	50-80	50-80	100
4.75 mm (No. 4)	20-100	25-100	33-55	25-50	25-50	50-100
1.18 mm (No. 16)	10-100	10-85	15-45	10-40	10-40	20-55
600 µm (No. 30)						
300 µm (No. 50)	5-90	5-40	5-22	2-20	2-20	10-30
150 µm (No. 100)	4-30			0-10	2-13	
75 um (No. 200)	0-10	0-8	a) 0-8 (gravel) b) 0-10 (quarry)	0-5	a) 0-8 (gravel) b) 0-10 (quarry)	0-12
M.T.C. Spec. No.	1010	1010	1010	1010 and 304, Class 2	1010	1010

1.4 **AGGREGATE QUALITY**

1.4.1 Refer to current M.T.C. Specifications for all products listed.

1.5 **Special Notes**

1.5.1 Material meeting the above aggregate gradations complies with the requirements of M.T.C.

1.5.2 Variations in aggregate gradations limits are permitted. The allowable tolerances are as detailed in the appropriate specification.

1.5.3 16 mm Crushed, Type "A" is similar to, and may be used for, "Surface Treatment", Aggregate, Class 2 M.T.C. 304. (additional sieves 2-38 mm - 15-47% passing; 600 um 5-35% passing).

1.5.4 Granular D consists of crushed rock or slag screenings

*changes to current specifications pending for 1982.

GROUP 2: COARSE AGGREGATE

2.1 **Coarse aggregate is a well-graded construction aggregate, graded between defined maximum and minimum allowable sizes; specified and identified in terms of the nominal size of the material and processed by means of crushing and/or screening, and washing as necessary, to conform to the product type and gradation requirements and standards of quality outlined in 2.3 and 2.4.**

2.2 **Source material may be: (i) quarried rock, (ii) sand-gravel deposits, (iii) iron, steel or nickel slags.**

2.3 **AGGREGATE GRADATION LIMITS**

Sieve Size	PERCENTAGE PASSING								
	PORTLAND CEMENT CONCRETE				ASPHALTIC CONCRETE			SURFACE TREATMENT	ROOFING
	*37.5 mm —No. 4	19 mm —No. 4	13.2 mm —No. 4	9.5 mm —No. 8	HL1 HL3	HL4	HL8	CLASS 1	
53 mm	100								
37.5 mm	95-100								
26.5 mm		100					100		
19 mm	35-70	90-100	100			100	90-100		100
16 mm		65-90			100	96-100	65-90		
13.2 mm			90-100	100	98-100	67-86		100	90-100
9.5 mm	10-30	20-55	40-70	85-100	50-73	29-52	20-55	75-100	40-70
6.7 mm								0-40	
4.75 mm (No. 4)	0-5	0-10	0-15	10-30	0-10	0-10	0-10	0-10	0-15
Spec. Ref.	CSA A23.1 and MTC 1002					MTC 303		MTC 304	ASTM D. 1863
					MTC 1003				

2.4 **AGGREGATE QUALITY**

2.4.1 **Portland Cement Concrete — refer to current C.S.A. Standard A 23.1 and M.T.C. Spec. 1002.**

2.4.2 **Asphaltic concrete — refer to M.T.C. specification 1003.**

2.4.3 **Surface-treatment — refer to M.T.C. specifications 303 and 304.**

2.4.4 **Roofing — refer to ASTM D. 1863.**

2.5 **Special Notes:**

2.5.1 **HL designates hot mix, hot-laid asphaltic concrete aggregate.**

2.5.2 **HL1 designates M.T.C. approved commercial sources.**

2.5.4 **37.5 mm — No. 4 nominal size concrete is frequently supplied in two separate sizes in order to minimize segregation, i.e. 37.5 — 19 mm (ref. 4.3) nominal size and 19 mm — No. 4 nominal size. The two aggregates are blended at the concrete plant facility to conform to the 37.5 mm — No. 4 specification requirement.**

2.5.5 **Steel slag is unsuitable for use for portland cement concrete aggregate. However it may be used for other aggregate purposes.**

2.5.6 **HL4, coarse aggregate is similar to, and may be used for, "Prime and Double Surface Treatment" coarse aggregate MTC 303.**

***specification may be deleted in 1982**

GROUP 3:
FINE
AGGREGATE

3.1 Fine aggregate is a construction aggregate processed by screening only, by crushing and screening, by air or water classification, or by blending suitably graded materials resulting from these processes to conform to the product type and the gradation requirements and standards of quality outlined in 3.3 and 3.4 respectively.

3.2 Source material may be: (i) quarried rock, (ii) sand-gravel deposits, (iii) iron, steel or nickel slags.

3.3 **AGGREGATE GRADATION LIMITS:**

Sieve Size	PERCENTAGE PASSING							
	PORTLAND CEMENT CONCRETE	CONCRETE BLOCK	MASONRY MORTAR	ASPHALTIC CONCRETE			*SURFACE TREATMENT CLASS 3	ICE CONTROL
				HL1, HL3	HL2	HL4, HL8		
13.2 mm		100						
9.5 mm	100	95-100		100	100	100	100	
6.7 mm								100
4.75 mm (No. 4)	95-100	65-85		90-100	85-100	85-100	85-100	90-100
2.36 mm (No. 8)	80-100	45-70	100	72-100	70-90	60-100	55-100	50-95
1.18 mm (No. 16)	50-85	30-55		50-90	50-75	34-90	30-90	20-90
600 um (No. 30)	25-60	15-40		32-70	30-55	17-70	15-70	0-70
300 um (No. 50)	10-30	8-25	15-40	14-40	15-35	9-40	5-40	0-35
150 um (No. 100)	2-10	0-15	0-10	5-15	5-16	3-15	0-10	0-15
75 um (No. 200)	0-3 Natural 0-5 Manufactured		0-5	0-5	3-8	0-7	0-7	0-5
FM	2.3-3.1		1.6-2.5					
Spec. Ref.	CSA A23.1		CSA A82.56 MTC 1004	MTC1003	MTC 306		MTC 303 and 304	MTC 530

3.4 **AGGREGATE QUALITY:**

3.4.1 Portland Cement concrete — refer to current C.S.A. Standard A23.1.

3.4.2 Asphaltic concrete — refer to current M.T.C. specification 1003.

3.4.3 Surface Treatment — refer to M.T.C. specifications 303 and 304.

3.4.4 Ice Control — refer to M.T.C. specification 530.

3.5 **Special Notes:**

3.5.1 HL2 aggregate gradation is identical to "Dense Graded Thin Bituminous Hot-Mix Surfacing" M.T.C. Form 306, except on the 4-75 mm sieve where the requirement is 84-100%, and on the 75 um sieve the requirement is 2-8% passing.

3.5.2 Variations in aggregate gradation limits are permitted. The allowable tolerances are as detailed in the appropriate specification.

*specification may be deleted in 1982.

GROUP 4: CLEAR AGGREGATE

4.1 Clear aggregate is a predominantly one-size construction aggregate, graded between defined maximum and minimum allowable sizes: specified and identified in terms of the nominal size of the material and processed by means of crushing and/or screening, and washing as necessary, to meet the specific requirements.

4.2 Source material may be: (i) quarried rock, (ii) sand-gravel deposits, (iii) iron, steel or nickel slags.

4.3 **AGGREGATE GRADATION LIMITS**

Sieve Size	PERCENTAGE PASSING		
	Nominal size		Ballast
	37.5 mm CLEAR	19 mm CLEAR	
53 mm	100		Refer to appropriate specifying authority
37.5 mm	90-100		
26.5 mm	20-55	100	
19 mm	0-15	75-100	
13.2 mm		0-15	
9.5 mm	0-5		

4.4 **AGGREGATE QUALITY:**
Refer to specifying authority.

GROUP 5: SPECIAL APPLICATION PRODUCTS:

5.1 **Armour Stone** is a stone in excess of 1 tonne and up to approximately 10 tonnes. This is obtained from the face of a quarry after blasting. Size depends on depth of bed and drilling pattern.

5.2 **Rubble** (face rock) is that material obtained from the face of a quarry after armour stone is removed. Size is dependent upon drilling pattern and will not necessarily be the same from one quarry to another. Rubble is very irregular in shape and size.

5.3 **Select Rubble** is that stone removed by shovel or loader taking particular care to have as little fines as possible.

5.4 **Rip-Rap** is a term to describe stones of various sizes from 305-508 mm which may be hand laid or machine laid on an embankment slope to prevent erosion. Spalls (smaller sized stones) or mortar may be used to fill in open joints. Reference: M.T.C. Form No. 511.

5.5 **Gabion Stone** ranges from 76-305 mm coming in various combinations, e.g. 106-152 mm, 178-305 mm. This material is often set in gabion baskets (wire mesh) and then placed upon another for slope stabilization and erosion control.

5.6 **Mineral Filler** consists of thoroughly dry limestone or other mineral powder conforming to the requirements of the appropriate specifying authority.

5.7 **Pit Run** is an unprocessed material obtained from deposits of sand or gravel, talus rock, quarries, slag, mine waste, clinkers or other suitable granular materials.

5.8 **Slurry Seal Aggregate** is the mineral component of the slurry seal process for pavement surface restoration.

5.9 **Interior Plaster Aggregate** consists of finely graded mineral components of perlite, vermiculite or sand conforming to CSA Standard A82.57 - 1954.

SPECIFICATIONS

Of the many specifications which describe the products listed in groups 1 to 4, the following are those which are normally used in Ontario.

Group 1 — Granular Base and Subbase

M.T.C. Form 1010 – Aggregate – Granular Base and Sub-base

Group 2 — Coarse Aggregate

Portland Cement Concrete

C.S.A. Standard A23.1 – Concrete Materials & Methods of Concrete Construction
M.T.C. Form 1002 – Aggregates – Concrete
A.S.T.M. C33 – Specification for Concrete Aggregates

Asphaltic Concrete

M.T.C. Form 1003 – Aggregates Hot-Mix Asphaltic Concrete

Surface Treatment

M.T.C. Form 303 – Prime and Double Surface Treatment
M.T.C. Form 304 – Surface Treatment with Bituminous Material

Roofing Aggregate

A.S.T.M. D 1863 – Mineral Aggregate for Use on Built-up Roofs

Group 3 — Fine Aggregate

Portland Cement Concrete

C.S.A. Standard A23.1 – Concrete Material & Methods of Concrete Construction
M.T.C. Form 1002 – Aggregate – Concrete
A.S.T.M.C33 – Specification for Concrete aggregates

Masonry Mortar

C.S.A. Standard A82.56 – Aggregate for Masonry Mortar

Asphaltic Concrete

M.T.C. Form 1003 – Aggregates – Hot-Mix Asphaltic Concrete
M.T.C. Form 306 – Dense Graded Thin Bituminous Hot-Mix Surfacing

Ice Control

M.T.C. Form 414 – Specification for Ice Control

Group 4 — Clear Aggregate

Ballast

C.N.R. – Ballast specifications
C.P.R. – Ballast specifications
A.R.E.A. – Ballast specifications

ABBREVIATIONS

M.T.C. – Ministry of Transportation & Communications (Ontario)

C.S.A. – Canadian Standards Association

A.S.T.M. – American Society for Testing & Materials

A.R.E.A. – American Railway Engineering Association

INDEX OF RECOMMENDED USES OF AGGREGATES

MATERIAL	USES																	REMARKS
	1 FOUNDATION BACKFILL	2 TRENCH BACKFILL	3 ROAD SUBBASE	4 ROAD BASE	5 STABILIZED BASE COURSE	6 UNTREATED ROAD SURFACE	7 CONCRETE AGGREGATE	8 ASPHALT SURFACE COURSE	9 ASPHALT BINDER COURSE	10 PARKING LOT SUBBASE	11 PARKING LOT BASE	12 WEEPING TILE BEDDING SEWER BEDDING	13 BASE FOR CONCRETE FLOORS & SLABS	14 RAILROAD BALLAST	15 EROSION CONTROL	16 SURFACE TREATMENT	17 OTHER	
GROUP 1 - GRANULAR BASE & SUB BASE																		
GRANULAR "C"	X	X	X							X								
GRANULAR "B"	X	X	X							X								
37.5 mm CRUSHED GRANULAR		X	X	X	X						X		X					
19 mm CRUSHED (GRANULAR "A")		X		X	X	X					X		X					
16 mm CRUSHED (TYPE "A")																X	X	MULCH
16 mm CRUSHED (TYPE "B")						X											X	SHOULDERING, MAINTENANCE
4.75 mm CRUSHED (GRANULAR "D") (SCREENINGS)	X	X	X	X	X					X	X		X					
GROUP 2 - COARSE AGGREGATE																		
37.5 mm - No. 4 PORTLAND CEMENT CONCRETE							X											PAVEMENT OR MASS CONCRETE POURS
19 mm - No. 4 PORTLAND CEMENT CONCRETE							X							X				CNR "B" BALLAST CPR NO. 5 BALLAST STRUCTURAL CONCRETE
13.2 mm - No. 4 PORTLAND CEMENT CONCRETE							X											THIN SECTION CONCRETE
9.5 mm - No. 4 PORTLAND CEMENT CONCRETE							X											THIN SECTION CONCRETE
HL1 ASPHALTIC CONCRETE								X										HIGH DENSITY TRAFFIC
HL3 ASPHALTIC CONCRETE								X										MEDIUM DENSITY TRAFFIC
HL4, HL5 ASPHALTIC CONCRETE								X	X							X		
HL6, HL8 ASPHALTIC CONCRETE									X									
SURFACE TREATMENT																	X	BITUMINOUS SURFACE TREATMENT FOR ROADS
ROOFING																	X	AGGREGATE FOR BUILT-UP ROOFING
GROUP 3 - FINE AGGREGATE																		
PORTLAND CEMENT CONCRETE							X											
CONCRETE BLOCK																	X	BLENDED AGGREGATE FOR CONCRETE BLOCK
MASONRY MORTAR																	X	SAND FOR MORTAR FOR MASONRY CONSTRUCTION
HL1, HL3 ASPHALTIC CONCRETE								X										
HL2 ASPHALTIC CONCRETE								X	X									
HL4, HL5 ASPHALTIC CONCRETE								X	X									
HL6, HL8 ASPHALTIC CONCRETE									X									
ICE CONTROL																	X	AGGREGATE FOR ICE CONTROL ON ROADS
SURFACE TREATMENT																X		
GROUP 4 - CLEAR AGGREGATE																		
37.5 mm CLEAR												X	X	X				CNR "A" BALLAST; CPR NO. 4 BALLAST
19 mm CLEAR												X	X					
GROUP 5 - SPECIAL APPLICATION PRODUCTS																		
ARMOUR STONE															X			
RUBBLE															X			
SELECT RUBBLE															X			
RIP-RAP															X			
GABION STONE															X			
MINERAL FILLER								X	X									
PIT RUN	X	X	X							X					X			
SLURRY SEAL AGGREGATE																	X	SURFACE RESTORATION
INTERIOR PLASTER AGGREGATE																	X	FINE AGGREGATES FOR INTERIOR SURFACES

QUALITY REQUIREMENTS FOR AGGREGATES

TYPE OF TEST / TYPE OF MATERIAL	COARSE AGGREGATE									FINE AGGREGATE					
	PETROGRAPHIC NUMBER MAXIMUM	$MgSO_4$ MAXIMUM % LOSS	ABSORPTION MAXIMUM %	LOS ANGELES MAXIMUM % LOSS	PERCENT CRUSHED MINIMUM	THIN AND ELONGATED PIECES MAXIMUM %	PASSING 75 µm MAXIMUM % (GRAVEL)	PASSING 75 µm MAXIMUM % (CRUSHED ROCKS)	CLAY LUMPS MAXIMUM %	$MgSO_4$ MAXIMUM % LOSS	PETROGRAPHIC ANALYSIS MAXIMUM	ORGANIC IMPURITIES MAXIMUM	SAND ATTRITION	PASS 75 µm	PLASTICITY INDEX
GRANULAR BASE A	200			60	50										0
16 mm CR. TYPE "B"	200			60	50		2·0								0
GRANULAR SUBBASE B	250														0
C	250														0
D															0
HOT MIX - H.L. 1	100	5	1·0	15	100	20	1·0	1·0		16	•		•	0-5	
2										20				3-8	
3	135	12	1·75	35	60	20	1·3	2·0		16				0-5	
4	160	12	2·0	35	60	20	1·3	2·0		20				0-7	
8	160	15	2 0	35	60	20	1·3	2·0		20				0-7	
SURFACE TREATMENT															
CLASS 1	135	12	1·75	35	60	20									
CLASS 2	160			35	60										
STRUCTURAL CONCRETE AND CONCRETE BASE	140	12	2·0	35		20	1·0	2·0	0·25	16	•	3	•	0-3	
PAVEMENT CONCRETE AND EXPOSED STRUCTURE DECK	125	12	2·0	35		20	1·0	2·0	0·25	16		3		0-3	

• TEST RESULTS ARE ANALYSED FOR SPECIFIC CONTRACTS, BUT THERE ARE NO CURRENT SPECIFICATION LIMITS

APPENDIX III

DATA ON DREDGED SAND
FROM
RED - D - MIX

RED-D-MIX

CONCRETE COMPANY
Division of STANDARD INDUSTRIES LTD.

QUALITY CONTROL LABORATORY

PLANT HAM DOCK DATE 84/10/22

SOURCE BOAT SAND (AVERAGE OF ALL LOADS)

ORGANIC - (TRACE)

LOSS BY WASHING ________

FLAT & ELONGATED ________

SPECIF. GRAVITY. ________
BULK BULK S.S.D. APPARENT

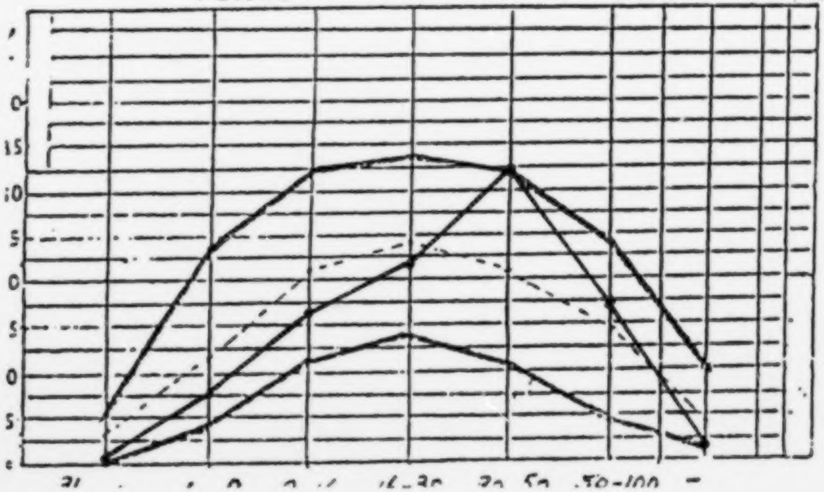
ABSORPTION ________

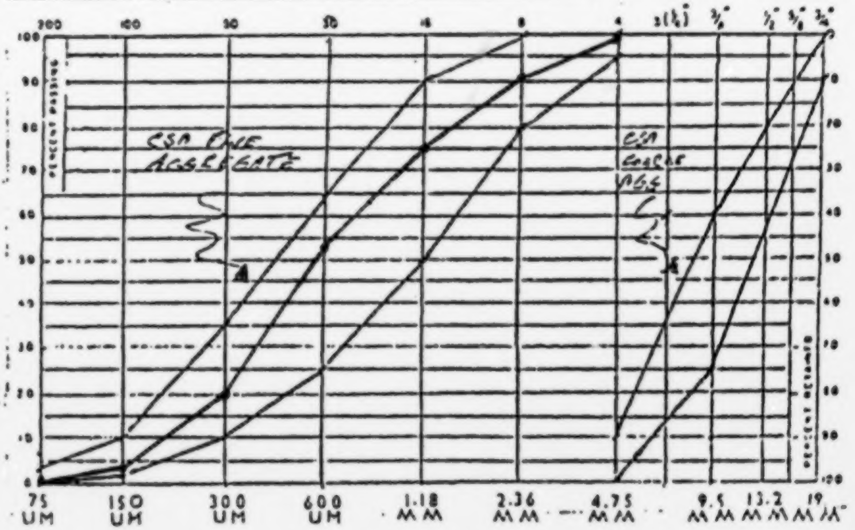
MECHANICAL SIEVE ANALYSIS

SIEVE	WEIGHT	PERCENT RET	 PASS	 CUM. RET.
1"				
3/4"				
5/8"				
1/2"				
3/8"				
#4		1	99.	1
#8		8	91.	9
#16		16.	75.	25
#30		22.	53	47.
#50		33.	20	80
#100		17.	3.	97.
#200		2.	1.	99.
PAN				2.59
TOTAL			F.M.	

SIGNED ________

PERCENT BETWEEN SIEVES





APPENDIX IV

INFORMATION FROM THE HYDRO ELECTRIC POWER COMMISSION OF ONTARIO ON DREDGED SAND

APPENDIX IVa

PETROGRAPHIC EXAMINATION OF DREDGED SAND FROM THE NIAGARA BAR

THIS COPY FOR → Mr. A.M. Burgess

THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO
RESEARCH DIVISION REPORT

To Mr. D.G. Watt,
Engineer-in-Charge,
Structural Research Dept.

PETROGRAPHIC EXAMINATION OF LAKE SAND

Sample:	S-4784
Symbol:	P-284
Received:	July, 1955
Location:	Lake Ontario
Description:	Natural Sand

Since the lake sand is used as a standard sand in the Concrete Laboratory and no petrographical description of it has been previously recorded, it seemed desirable to complete examinations started some time ago and to record the results.

The detailed results and comparisons with some natural sands from the St. Lawrence area, are presented in the Appendix.

Discussion of Results

The most typical feature about the composition of lake sand was the fact that 3/4 of the sample consisted of calcareous rocks, sandstone and quartz particles, each constituent in almost equal amounts. In assessing the quality of lake sand, however, the presence of chert and material floatings on a fluid of specific gravity 2.0 are the important ones to be considered.

Chert

The sand fractions (passing No. 4 sieve size) contained an average of 9.2 per cent chert but its amount in the average portion was 27.3 per cent. Such a distinct decrease of chert in finer fractions (No. 28 and finer) was also found in sands very rich in chert deriving from other localities (cf. Reference No. 1). Since all varieties of chert are

JOB	FILE	DATE	REPORT No.
740617-22-4015	821.14	August 13, 1957	M57-40

not deleterious an attempt was made to classify the cherts found in the sample as: (a) suspected of being deleterious and (b) innocuous. The weathering and porosity were taken as the basis for such distinction; this detailed examination, however, was performed only on chert particles of the No. 8 fraction because only in this fraction were the particles sufficiently numerous and large (Table 4). The proportions of the varieties found in the No. 8 fraction were then assumed to apply in the rest of the sample. The amount of "harmful" chert particles calculated on this basis was 1.4 per cent in the sand portion proper and 3.9 per cent in the oversize. But it is felt that these percentages were rather conservative.

The percentage of light material (floating on fluid of 2.0 spec. gravity) was relatively small according to the A.S.T.M. test method but was somewhat higher in the three fractions when tested separately (Table 5). When the coal particles in the oversize fraction, (not all of which floated,) are included with the light weight material the percentage of light material, there, was higher.

Thus, the percentage of harmful particles in the oversize fraction distinctly exceeded the 5.0 limit of Hydro specification for aggregate for mass concrete. However, in the sand size portion which formed over 95 per cent of the sample, the undesirable particles amounted to only 3.3 per cent.

Conclusion

Petrographical examinations have shown that the lake sand sample contained a relatively large percentage of chert particles especially in the oversize fraction, however, the extent of harmfulness of chert in the lake sand is not known; other harmful material was also found in the sand and its quantity increased in the oversize fraction.

Although the lake sand has given in general, a satisfactory performance record for many years, it is felt that variations in the composition were responsible for some erratic results encountered during the investigation of St. Laurence aggregates when lake sand was used as the reference fine aggregate. On the other hand it must be expected that such sand deposits (a large lake) will provide products which vary in composition and quality to a certain extent.

The presence of relatively large amounts of chert and different varieties of it also seems to indicate that for research purposes the durability of the chert in lake sand be assessed by specific tests.

Submitted:

L. Dolar-Mantuani

L. Dolar-Mantuani,
Petrographer,
Masonry Section.

LDM/TB

References

1. K. Mather and J. Weiler Silverman, "The Petrography of Aggregates for Mass Concrete", Bull. No. 39, Waterways Exp. St. Corps. of Eng. U.S. Army, 1954.

2. Report M53-15 "Petrographic examination of foreign material in a recent delivery of lake sand", by L. Dolar-Mantuani; file 36.4.232; February 19, 1953.

APPENDIX

Test Methods

The sample was examined in the routine way with the petrographical and stereoscopic microscopes. Additional investigations included the following tests:

(1) Determination of the amount of acid insoluble residues was performed on all fractions save the oversize No. 4 fraction. The test was repeated by paying special attention to take at least 300 particles in each (also coarser) sand fraction.

(2) Heavy liquid separations were made on No. 48 to No. 100 fractions with a heavy liquid having a specific gravity of 2.88 and on No. 8 to No. 28 fractions as well as on combined No. 8 to No. 48 fractions (A.S.T.M.) with a liquid having a specific gravity of 2.0.

(3) To investigate the chert types more in detail, 300 grains of chert were collected from the No. 8 fraction and divided into different varieties under a stereoscopic microscope. Two chert particles were, further more, examined in thin sections and several others in mounted slides.

DESCRIPTION OF SAND PARTICLES

Carbonate rocks:

Destinction between the compact, aphanitic limestone and the finegrained, usually lighter gray dolomitic rocks was made only in coarser fractions. The particles are usually rounded and smooth, especially those of limestone. The degree of weathering of dolomitic siltstone (leaving abundant minute silicate grains after HCI-dilute. reaction) was relatively slight.

Sandstones:

some dolomitic sandstones in the oversize fraction were friable; other sandstones, white or brownish in colour were rarely brittle; the amount of carbonate constituents varied widely; the brownish sandstones contained finely distributed limonite in the matrix. Sandstone cemented in situ was found only in the oversize fraction. By increasing amounts of limonite the sandstone seemed to be better classified as ironstone and became physically weak. White sandstones, which did not mainly break through the matrix and had a smoother surface were listed as quartzites.

Shale:

Particles developed abundant clayey deposit with HCl dil. but only some decomposed easily when wetted and were considered poor and deleterious.

Silicate rocks (igneous, metamorphic):

The distinction among various types was made on the basis of structure and presence of mafics. The particles seemed to be only slightly weathered.

Chert particles were sharp-angular or rounded, their surface usually smooth, rarely rough, caused by weathering. A distinction into several varieties was made on the basis of colour and porosity (Table 4); only the porous particles were regarded as potentially deleterious.

The thin sections (T.S.788 and 789) and numerous mounted sections showed that the chert particles consisted mainly of minute isometric grains (mosaic texture). Typical microfiberous chalcedony texture was usually visible only in small areas. However, the refractive index of both aggregates, being lower than 1.54, indicated chalcedony as the main components. Most of the particles contained various amounts of carbonates in the form of well developed rhombohedrons or fine-grained aggregates. The brownish varieties contained limonitic impurities in the form of minute concentrations in chalcedony or carbonates. No opal was detected.

Mineral Constituents

The most frequent constituent was quartz which was usually colourless, isometric and angular. Quartz with brownish limonitic impurities found in the finer fractions, seemed to derive from decomposed sandstones. The other mineral particles consisted mostly of single grains which were prevalently isometric (also amphiboles) and angular. The minerals seemed to be fresh and even the feldspars only slightly weathered.

All fractions, but the -No. 100, contained a few broken pieces of whitish shell particles which were fragile.

Particles, mostly floating on fluid of specific gravity 2.0, were investigated in fractions up to +No. 100 and consisted of slag, coal and wooden pieces (Table 5). The slag particles were usually, porous, mostly black, some white, brownish or grayish. Several particles were distinctly viterous and then heavier than 2.0 (cf. Reference No. 2 for more detailed description). Coal particles were relatively compact but soft. The pieces of wood were weathered.

TABLE I

PARTICLE SHAPE OF LAKE SAND
(P-284, S-4784)

	Retained on Sieve Sizes						Pass	Total
Shape of Particles	No. 4	No. 8	No. 14	28	48	100	No. 100	No. 8 to -No. 100
Rounded, subrounded								
Cubic	28	26	13	12	13	3	2	13
Flat	10	2	1	1				1
Oblong								
Angular, subangular								
Cubic	54	69	85	85	87	96	96	85
Flat	7	3	1	2	x	1	2	1
Oblong	1	x	x				x	x
	100	100	100	100	100	100	100	100

---

x - amounts less than one per cent.

TABLE 2

COMPOSITION OF LAKE SAND
(P-284, S-4704; in per cent)

Sieve Size Per cent retained	No. 4 4.3	No.8 18.6	No.14 24.9	No.28 [illegible]	No.48 18.8	No.100 14.9	P.100 [illegible]	Total of No.8 to -10
Limestone	2.8	3.4	3.6	6.6	6.0	5.9	3.1	4.8
Dolomite	12.2	14.1	18.1	14.6	4.3			10.5
Shaly Dolomite	.7	.3	1.3	.3				.4
Dolomitic siltstone	2.5	9.4	14.1	12.0				7.5
Dolomitic siltstone, slightly weath. (deleterious ?)	1.1	.7						.1
Dolomitic sandstone	4.9	4.2	2.0					1.3
Dol. sandstone (poor, deleterious)	.7							
Siltstone gray non-carbon aceous	4.2	3.7	1.6					1.1
Sandstone, white	8.3	15.4	14.7	14.6	11.2	2.8	1.5	11.8
Sandstone (fair)	.4	.3	.3					.1
Sandstone brownish	16.0	12.1	9.8	7.1	3.4	3.6	1.8	7.3
Sandstone, poorly cemented (poor)		.7						.1
Ironstone (Fair)			1.0			3.0	1.8	.8
Ironstone (poor, deleterious?)			.3	1.0				.3
Shale (fair, deleterious?)		.6	.5		.7	.4	1.2	.5
Shale, black (poor, deleterious)			.3	.8				.2
Quartzite	5.3	4.0	3.9	1.0				1.9
Granite, aplite	3.2	5.0	4.6	9.0	3.9	1.2		4.7
Gneiss	2.5	2.7	.7	.6				.8
Trap	.4	.3	.3					.1
Metam. rocks	.7							
Chert (deleterious?)	27.3	20.6	15.7	5.5	1.5	1.1	.6	9.2
Quartz		1.7	3.9	22.8	58.3	47.3	28.6	24.7
Quartz with limonite						14.9	14.1	2.8
Feldspar			1.6	3.9	4.0	9.3	3.1	3.4
Carbonate					3.1	3.2	32.4	2.4
Amphibole					1.9	2.9	3.2	.9
Pyroxene					.3	.4	1.0	.2
Garnet					.4	1.5	1.5	.4
Mica, Chlorite (poor)						.3	2.7	.2
Accessory minerals*					.3	1.3	.3	.3
Opaque minerals						x	2.1	.1
Limonite fair, (deleterious)					.2	.8	1.0	.2
Clayey lumps (poor, deleterious)	.4							
Shell (poor)	.4	x	x	x	x	.1		x
Slag	3.2	.3	1.2	1.0	.3			.6
Coal (poor)	2.8	.3	.3	.2	.2			.2
Wood (poor)		.2	.2	x				.1
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

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x - Amounts less than 0.1 per cent.

* - Accessory minerals additional to the mentioned: Staurolite, epidote, tourmaline, sphene, zircon, apatite (?).

TABLE 3

PHYSICAL AND CHEMICAL QUALITY OF LAKE SAND (P-284, S-4784)

Physical Quality	No. 4 Per Cent	No.8 to -No.100 Per Cent
Good Particles	95.3	97.3
Fair Particles	.4	1.6
Poor Particles	4.3	1.1
	100.0	100.0

Chemical Quality	A	B	A	B
Innocuous Particles	70.5	93.9	89.5	97.3
Deleterious? Particles	28.4	4.8	10.1	2.2
Deleterious Particles	1.1	1.3	.4	.5
	100.0	100.0	100.0	100.0
Sum of poor and deleterious particles		9.3		3.3

Poor particles, No. 4 fraction: dolomitic sandstone, weathered, friable; clay lumps, shell, coal.

No. 8 to -No. 100 fractions : poorly cemented sanstone, ironstone, weathered shale, mica, chlorite, coal, wood.

Deleterious particles, No. 4 fraction : dolomitic sandstone weathered; clay lumps.

No. 8 to -No. 100 fraction : weathered shale, limonite.

Particles, suspected of being deleterious,

No. 4 fraction : slightly weathered dolomitic siltstone, chert*

No. 8 to -No. 100 fraction : Slightly weathered dolomitic siltstone, ironstone, shale, chert*

---

* For distinction between various types of chert, see Table 4

a - amount of chemically unsound material determined by including all chert particles into suspicious material.

b - amount of chemically unsound material determined by dividing the percentage of chert particles according to varieties as found in fraction No. 8, Table 4.

TABLE 4

CHERT VARIETIES IN FRACTION NO.3 OF LAKE SAND (P-284. S-4784)

Characteristics	Per Cent	
Chert, compact, medium dark grey (N4)	37.3	
Chert, compact, olive gray (5Y5/1) to brownish gray (5YR4/1)	28.0	
Chert, compact, dark yellow brown (10YR4/2) to very pale orange (10YR7/2)	13.7	
Chert, gray to brownish, part of surface rough, weathered	6.7	
Chert, slightly porous, medium olive gray (5Y5/1)	8.3	13.6 deleterious.
Chert, various colours, slightly porous	5.3	
Chert, porous, weathered moderate yellowish brown (10YR5/2)	.7	deleterious

TABLE 5

VARIOUS TEST DATA OF LAKE SAND (F-23½, S-4784) (in per cent)

Fractions	Grading	Acid insoluble residue		Float on fluid Sp. gr. 2.0		Sink in fluid Sp. gr. 2.88
			Repeat			
No. 8 Retained	18.6	75.4	75.3	.8		
No. 14 "	24.0	66.3	67.7	.7	.255*	
No. 28 "	18.6	65.0	62.7	.3		
No. 48 "	16.8	80.7	80.7			11.2
No. 100 "	14.9	91.4	89.7			11.2
No. 100 Passing	4.2	68.7	67.3			35.6
Total		74.3	73.9			

* Particles floating on fluid of specific gravity 2.0 are (test performed on combined fractions No. 8 to No. 48): slag particles, mostly black, some white, brownish or grayish (3/4 of the floating material), coal, particles of wood, single particles of weathered rocks, muscovite and finest grains of desintegrated slag and rocks.

TABLE 6

COMPARISON OF CHARACTERISTICS OF LAKE SAND AND DIFFERENT NATURAL SAND SAMPLES FROM THE ST. LAWRENCE AREA

Location	P-No.	S-No.	Composition in per cent Sediment	Igneous, Metamorphic rocks	Minerals	Quality in Per Cent Poor	Deleterious	Deleterious?	Harmful Combined	% lighter than 2.0	Spec. Gravity	Absorption %	% Weight loss in Na-Sulphate test
Joliette, Loc. 84	197	4536	-	26.8	73.2	.4	.3	2.4/1/			2.68	.54	.83
Snyder Pit	285	4819	17.9	19.1	63.0	1.5	.2	2.2	3.6	.02	2.66	1.30	3.66
Grenadier Island Loc. 85	227	4639	18.1	16.7	65.2	2.1 2.1	1.4 .5	.8/1/ 2.5/2/	4.6		2.68	.65	1.93
" "		4624									2.71	1.61	3.35
Melone, Paro Pit Loc. 9 U.S.A.	204	4549	31.9	10.2	57.9	2.2 2.2	2.3 2.0	.4/1/ 1.5/2/	3.6		2.68	1.09	3.27
Lake Sand	284	4784	58.8/3/	5.8	35.4	1.1	.5	2.2	3.3	.27	2.65	1.72	4.55
Mixture Loc. 10 and 23	264	4758	60.8	6.3	32.9	2.8 2.8	2.6 2.6	.2/1/ .4/2/	3.2		2.69	1.13	2.54
Finch-La Chapelle Loc. 10		4469									2.68	1.05	2.72

/1/ Only half of the cloudy feldsparsare listed under suspected of being deleterious

/2/ The entire percentage of cloudy feldspars and some of the weathered rock particles listed previously under deleterious are included in the groups of particles suspected of being deleterious (?)

/3/ Slag particles (0.6 per cent) included into the groups of sediments.

THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO
RESEARCH DIVISION REPORT

To Mr. H.C. Ross, Asst Director of Research
Att. Mr. D.R. Kempton

PETROGRAPHIC EXAMINATION OF FOREIGN MATERIAL IN A RECENT DELIVERY OF LAKE SAND

Introduction

The detection of foreign material in a recent delivery of Lake sand resulted in a request for its identification in oversize fractions of this fine aggregate which is to be used in concrete proportioning studies for Sir Adam Beck Niagara G.S. No. 2.

The material was examined with a lens and a stereoscopic microscope. The solubility in HCl and the combustibility were determined.

Description of the Particles

Most of the particles are relatively light, dark gray and angular of flaky, prismatic or cubic shape. They show characteristical glassy luster, conchoidal fractures and black colour on the recently broken surfaces. They have evidently been sintered and can be classified into two groups according to porosity. One type of particle is highly porous with spherical voids; the other is more compact, shiny, and usually has a parallel structure which is underlined by bright, minute crystalline grains. The latter are developed in even greater numbers in the porous type. Occasional particles with a parallel structure are whitish or whitish and dark on two opposite sides.

Neither the dark nor the whitish particles react with HCl. Heating a compact black particle did not cause any change in its appearance.

JOB	FILE	DATE	~~SUB-CLASS~~	REPORT No.
V 2173	36.4.232	February 19,1953	Symbol P-132	M 53-15

Conclusion

All these properties conform best with furnace or smelter slag. The crystalline grains found in voids and on the surface of particles normally accompany glassy products. The more compact particles, forming about a half of the foreign material, seem to be partially fused coal rich in impurities which was able to retain its original structure under specific conditions. The whitish particles seem to differ by the complete ignition of coal and the lack of iron. The angular shape is caused by the brittleness of the slag.

Analysis of eleven samples indicated that the percentage of this slag in the oversize material varies from 0.8 to 7.0 with an average of 2.7 percent. This content in the oversize material, which constitutes only 6 percent of the total sand, would represent an over-all content of 0.16 percent; and while some cinder foreign material is certainly also present in its finer fractions, the content is probably very low.

The relatively small amount of this material in the sand and the fact that the relatively inert material possesses fair structural strength would indicate that little harmful effect is to be expected by its presence. It might be well, however, to check on the source of the mechanism of its deposition in the sand to better evaluate the possibility of more serious pollution of the sand.

Submitted by,

L. Dolar-Mantuani

L. DOLAR-MANTUANI
Research Petrographer

LD-M/EJ
cc: Mr. A.M. Burgess

APPENDIX IVb

PHYSICAL PROPERTIES AND GRAIN SIZE ANALYSIS OF DREDGED SAND FROM THE NIAGARA BAR

THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO
STRUCTURAL RESEARCH DEPARTMENT
MASONRY AND SOILS SECTION

SIR ADAM BECK N.G.S. NO.2 - PHYSICAL PROPERTIES OF CONCRETE AGGREGATES

January, 1952

Material	Serial	Specific Gravity			Absorption	Voids	Moist.	Unit Weight			Soundness		Material Passing No.200 Sieve
	No.							Lb./Cu. Ft.			Sod.Sulphate		
		Bulk Sat. and. S.D.	Bulk Oven Dry	Apparent	%	%	%	Dry Rodded	Dry Loose	Moist Loose	Failures 5 cyc.	Failures 20 cyc.	%
Niagara Bar Sand	S-3952	2.60	2.55	2.67	1.67	-	3.60	114.30	107.67	87.45	1.07 *	-	1.75
Telephone City Sand	S-3879	2.65	2.61	2.71	1.42	-	4.55	100.70	93.44	77.15	0.73 *	-	3.40
Paris Sand	S-3880	2.76	2.73	2.80	0.61	-	4.28	114.10	104.90	87.30	4.04 *	-	2.76
Gasport Limestone	S-3953	2.72	2.69	2.79	1.24	47.59	-	91.40	84.30	-	0	3	-
Lockport Dolomite	S-3954	2.74	2.71	2.80	1.13	47.00	-	90.55	83.47	-	3	3	-
Paris Sand-5 Pts. Tel.City Sand-1 Pt.	S-3880 S-3879	2.65	2.63	2.69	0.85	-	3.52	110.47	105.09	87.49	-	-	-

COEFFICIENTS OF THERMAL EXPANSION

Material	Coefficient of Thermal Expansion X 10^6/Deg. F.
Lockport Dolomite	4.8
Gasport Limestone	5.0
Lake Sand	5.2
Paris/Telephone City Sand	4.5

Averages only - See Report, Thermal Expansion of Aggregates, SABGS No. 2, December, 1951.

* Weighted per cent loss. Sodium Sulphate Soundness Test on S-3879 was Carried Out on One Size of Material Only.

AMB:JG

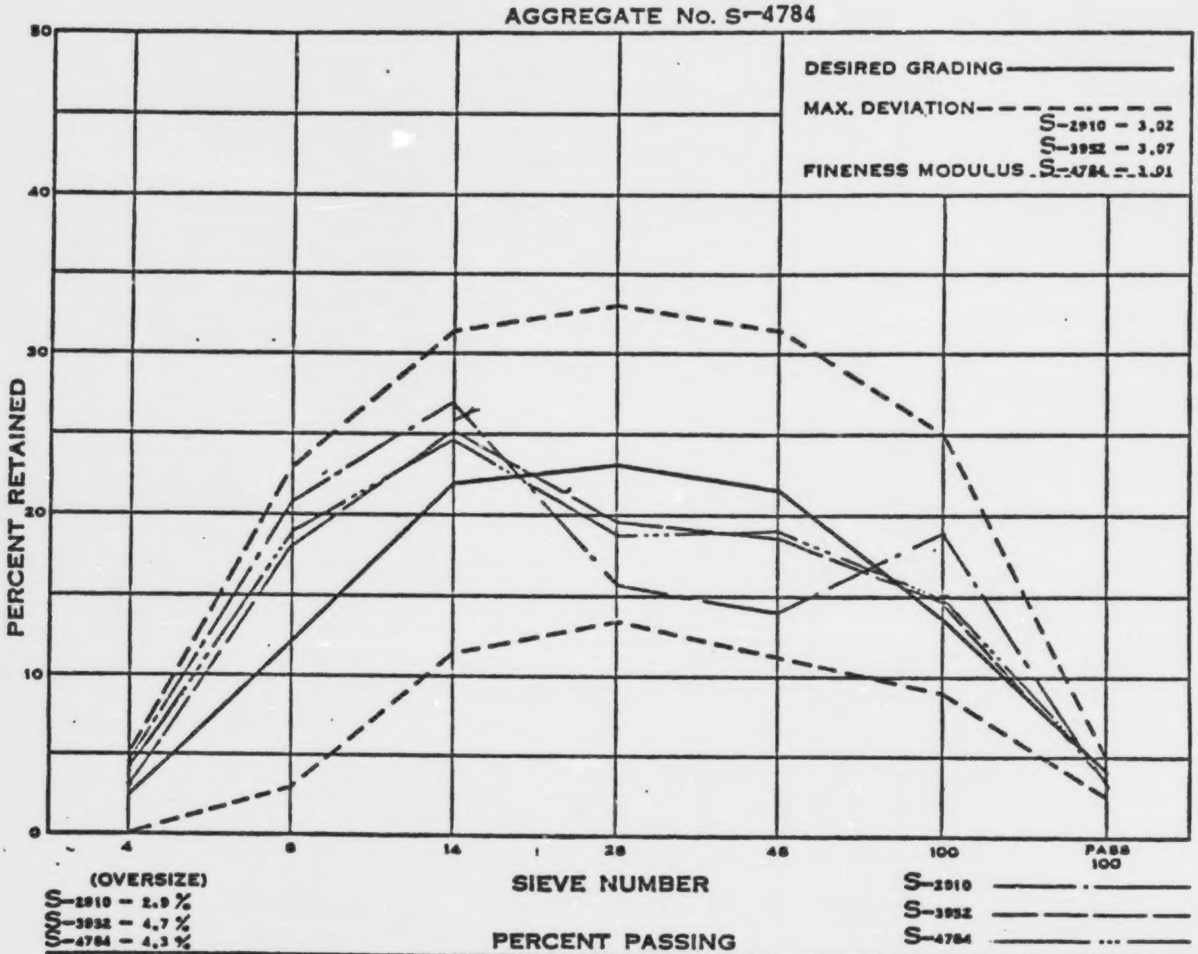
H.E.P.C. NO. 1686 25 PADS-4-49
PRINTING DEPT.

THE HYDRO ELECTRIC POWER COMMISSION OF ONTARIO

STRUCTURAL MATERIALS LABORATORY

GRAPHIC REPRESENTATION OF SIEVE ANALYSIS OF SAND

S—2910
S—3952
AGGREGATE No. S—4784



PERCENT PASSING

	No. 4	No. 8	No. 14	No. 28	No. 48	No. 100	PASS 100
S—2910	100.0	82.0	56.6	37.1	18.5	3.7	
S—3952	100.0	79.0	51.9	36.4	22.4	3.5	
S—4784	100.0	81.4	56.5	37.9	19.1	4.2	

REMARKS:

S—2910 – 44 TONS NIAGARA BAR SAND TRUCKED FROM DECEW FALLS JOB STOCKPILE SEPTEMBER 1946.

S—3952 – 50 TONS NIAGARA BAR SAND TRUCKED FROM QUEENSTON DOCK SEPTEMBER 1951.

S—4784 – 47 TONS NIAGARA BAR SAND TRUCKED FROM STOCKPILE AT SIR ADAM BECK N.G.S. No. 2 MAY 1955.

REPORTED BY

D. G. WILKINSON

STRUCTURAL MATERIALS LABORATORY

100896—RD

NIAGARA BAR SAND FROM DECEW FALLS

FOR

LABORATORY INVESTIGATIONAL WORK

S-2910

September 1946

Date 1946		Truck Load No.	Per cent Oversize	Mechanical Analysis					Fineness Modulus
				Per cent Passing - Sieve Size					
				No. 8	No. 14	No. 28	No. 48	No. 100	
Sept.	23	1	3.2	81.6	54.9	33.4	15.7	3.4	3.11
"	23	2	5.3	81.2	54.8	34.4	16.4	3.2	3.10
"	24	3	2.2	82.6	57.4	37.4	18.7	3.9	3.00
"	24	4	1.6	81.0	56.1	37.6	18.9	3.8	3.03
"	24	5	1.5	83.2	58.4	39.0	20.0	3.8	2.96
"	24	6	3.4	82.4	59.0	41.1	21.5	4.0	2.92
Average of six loads approx. 44 tons									
			2.9	82.0	56.8	37.1	18.5	3.7	3.02

Lake Sand From DeCew Falls

For

Laboratory Investigational Work

December, 1946

Date 1946	Truck Load No.	Percent Oversize	Sieve Analysis Percent Passing No. 8	No.14	No.28	No.48	No.100	Fineness Modulus
Sept. 23	1	3.2	81.6	54.9	33.4	15.7	3.4	3.11
" 23	2	5.3	81.2	54.8	34.4	16.4	3.2	3.10
" 24	3	2.2	82.6	57.4	37.4	18.7	3.9	3.00
" 24	4	1.6	81.0	56.1	37.6	18.9	3.8	3.03
" 24	5	1.5	83.2	58.4	39.0	20.0	3.8	2.96
" 24	6	3.4	82.4	59.0	41.1	21.5	4.0	2.92

Average of 6 loads approx. 44 tons

S-2910

		2.9	82.0	56.8	37.1	18.5	3.7	3.02

AMB/MP

The Hydro Electric Power Commission of Ontario
Structural Research Department
Masonry and Soils Section

Niagara Bar Sand From Queenston Dock
For
Laboratory Investigational Work

Sept. 1951

Truck No.	Oversize Percent	SIEVE ANALYSIS Percent Passing - Sieve Size					Fineness Modulus
		No.8	No.14	No.28	No.48	No.100	
1	6.9	75.8	49.1	34.2	21.0	3.6	3.16
2	7.0	75.7	47.8	33.2	20.1	3.6	3.20
3	3.5	80.6	53.4	37.6	23.5	2.8	3.02
4	2.3	82.9	57.5	42.2	27.1	4.2	2.86
5	4.0	79.2	51.7	35.8	21.5	3.6	3.08
6	4.2	79.6	51.9	35.5	21.4	3.2	3.08
		Average of Six Loads - 50 Tons					
		S-3952					
	4.7	79.0	51.9	36.4	22.4	3.5	3.07

AMB/MP

NIAGARA BAR SAND FROM QUEENSTON DOCK

FOR

LABORATORY INVESTIGATIONAL WORK

S-3952

September 1951

Truck No.	Oversize Per cent	Mechanical Analysis					Fineness Modulus
		Per cent Passing - Sieve Size					
		No. 8	No. 14	No. 28	No. 48	No. 100	
1	6.9	75.8	49.1	34.2	21.0	3.6	3.16
2	7.0	75.7	47.8	33.2	20.1	3.6	3.20
3	3.5	80.6	53.4	37.6	23.5	2.8	3.02
4	2.3	82.9	57.5	42.2	27.1	4.2	2.86
5	4.0	79.2	51.7	35.8	21.5	3.6	3.08
6	4.2	79.6	51.9	35.5	21.4	3.2	3.08
Average of six loads - 50 tons							
	4.7	79.0	51.9	36.4	22.4	3.5	3.07

NIAGARA BAR SAND FROM STOCKPILE AT SIR ADAM BECK N.G.S. NO. 2

FOR

LABORATORY INVESTIGATIONAL WORK

S-4784 May 1955

Truck No.	Oversize Per cent	Mechanical Analysis					Fineness Modulus
		Per Cent Passing - Sieve Size					
		No. 8	No. 14	No. 28	No. 48	No. 100	
1	4.4	81.4	56.9	38.9	19.1	4.0	3.00
"	4.0	82.7	57.1	38.8	19.1	3.9	2.98
2	4.4	81.2	56.2	38.6	20.3	4.4	2.99
"	5.0	80.3	55.2	38.4	20.4	4.4	3.01
3	5.1	81.0	56.0	37.2	19.2	4.2	3.02
"	3.8	81.0	55.2	37.0	19.0	4.3	3.04
4	5.0	80.2	55.9	36.4	17.7	3.8	3.06
"	3.6	82.7	57.3	37.0	17.7	3.6	3.02
5	3.7	81.7	57.1	37.6	17.8	4.0	3.02
"	3.9	81.3	57.4	37.8	17.9	4.1	3.02
6	5.0	81.3	55.9	38.2	20.6	4.8	2.99
"	3.9	81.0	56.6	38.4	20.7	4.7	2.99
7	4.0	82.8	58.1	38.8	19.3	4.0	2.97
"	4.8	80.5	55.7	37.6	19.0	4.1	3.03

Average of seven loads - 47 tons - two mechanical analyses taken from each load.

	4.3	81.4	56.5	37.9	19.1	4.2	3.01

APPENDIX IVc

ALKALI - AGGREGATE REACTION
TESTS ON CONCRETE AGGREGATES

H.E.P.C. [illegible]

THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO
RESEARCH DIVISION REPORT

To Mr. H.C. Ross,
Engineer-in-Charge,
Structural Research Department.

SUBJECT: Alkali-Aggregate Reaction Tests On Concrete Aggregates Proposed For Use At Sir Adam Beck-Niagara G.S. No. 2

The tests herein reported were conducted to determine the alkali-reactive properties of concrete aggregates proposed for use at Sir Adam Beck-Niagara G.S. No. 2.

The tests consisted of length change measurements made on 1" x 1" x 10" mortar bars proportioned 1:2 and stored in moist air in sealed containers at a temperature of 110°F.

Length change measurements were made at the intervals shown on the attached tables.

A summary of the aggregates tested or in the process of being tested is shown on Table I.

When specimens representing an aggregate, attained a test age of 20 months without evidence of excessive expansion the test was concluded.

The expansion recorded for any one aggregate, regardless of proportions to the filler material, is less than the proposed ASTM allowable expansion of 0.10 percent in 12 months.

Submitted by,

A. M. Burgess

A.M. BURGESS,
Foreman,
Masonry and Soils Section.

AMB:JH
Attachs:

JOB V2173	FILE 36.4.220	DATE January 19, 1953.	SUBJ. CLASS	REPORT No. M53-8

THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO

STRUCTURAL RESEARCH DEPARTMENT

Masonry and Soils Section

ALKALI REACTIVE TESTS
SIR ADAM BECK-NIAGARA G.S. NO. 2
MOYER'S SAND, S-3846

TABLE 3

AGGREGATE PROPORTIONS		AGE IN DAYS							
		39	67	101	135	164	198	233	255
		PERCENT EXPANSION							
Dundas C.R.	S-3846								
100	0	.016	.022	.022	.024	.025	.026	.022	.020
94	6	.018	.023	.025	.024	.026	.024	.024	.020
88	12	.017	.023	.023	.024	.026	.025	.024	.020
75	25	.017	.022	.024	.027	.030	.025	.024	.024
50	50	.015	.017	.019	.023	.025	.020	.019	.017
0	100	.017	.023	.025	.031	.028	.021	.022	.018

NOTE:
1. Specimens are 1" x 1" x 10" bars
2. Dundas Crushed Stone used as filler
3. Each result represents the average of three specimens.
4. Proposed ASTM Limit of Expansion is 0.10 percent at 12 months.

This test was discontinued on November 1, 1951 due to the fact that the sand was not being used on the job and the space occupied by the sample in the conditioning cabinet was required for job materials.

Tested and Reported

Masonry and Soils Section.

/MB:JH

THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO
STRUCTURAL RESEARCH DEPARTMENT
Masonry and Soils Section

ALKALI REACTIVE TESTS
SIR ADAM BECK-NIAGARA G.S. NO. 2
LAKE SAND, S-3952

TABLE 9

AGGREGATE PROPORTIONS		AGE IN DAYS 34	64	97	132	162	195	231	254	288	315	345	378	407	436
		PERCENT EXPANSION													
Dundas C.R.	S-3952														
100	0	.021	.017	.025	.026	.023	.026	.025	.023	.027	.027	.027	.027	.024	.022
94	6	.019	.015	.024	.026	.025	.027	.026	.024	.028	.028	.028	.029	.026	.024
88	12	.019	.015	.024	.025	.021	.022	.021	.018	.022	.022	.023	.022	.021	.017
75	25	.021	.020	.028	.030	.027	.028	.028	.023	.029	.030	.030	.030	.030	.025
50	50	.020	.021	.029	.033	.033	.031	.034	.029	.034	.035	.036	.034	.036	.030
0	100	.008	.010	.019	.024	.025	.021	.021	.017	.022	.025	.024	.022	.023	.019

NOTE:
1. Specimens are 1" x 1" x 10" bars
2. Dundas Crushed Stone used as filler
3. Each result represents the average of three specimens.
4. Proposed ASTM Limit of Expansion is 0,10 percent at 12 months.

Tested and Reported

AMB:JH

Masonry and Soils Section

THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO

STRUCTURAL RESEARCH DEPARTMENT

Masonry and Soils Section

TABLE I SUMMARY OF ALKALI-AGGREGATE REACTION TESTS JANUARY, 1953

Serial No.	Aggregate	Duration of Test Days	Maximum Expansion Percent	Status of Test
S-3807	Decew Dolomite - Crushed Rock	639	.056	Discontinued
S-3846	Moyer's Sand	255	.031	Discontinued
S-3847	Queenston Crushed Rock	693	.032	Discontinued
S-3863	Undifferentiated Lockport Dolomite C.R.	636	.038	Discontinued
S-3864	Gasport Limestone - Crushed Rock	631	.037	Discontinued
S-3880 S-3879	Paris Sand 5 Parts)) Blend Telephone City Sand 1 Part)	438	.039	Continuing
S-3880	Paris Sand	450	.039	Continuin
S-3952	Lake Sand - Laboratory Standard	436	.036	Continuing
S-3953	Gasport Limestone	434	.039	Continuing
S-3954	Lockport Dolomite	440	.045	Continuing

* Used in original proportioning studies for the tunnel concrete.

AMB:JH

APPENDIX V

SUMMARY OF SEDIMENT / GRAIN SIZE DATA
FROM DR. P. SLY (CCIW)

The following data provides a listing of parameters measured on surficial sediment samples obtained from three areas in the Great Lakes (see Figure 1) [ref. 1].

Area 1 - Niagara bar, Lake Ontario

Sample numbers 1 to 281

Area 2 - Near Tobermory, Georgian Bay

Sample numbers 282 to 562

Area 3 - Near Kingston, Lake Ontario

Sample numbers 563 to 843

These sediment samples were obtained with a double Shipek sampler (ref. 2) on a pre-determined fixed grid. At the beginning of the data set for each area there is a line printer plot of the relative position of each sample station (schematic plot and not to scale).

Table 1

1) Stn. No. - Station number

2) Cell Size - each sample area is composed of sixteen units (4 x 4);
- each unit consists of five nested squares or cells, with samples taken at the corner of each square (cell);
- square (cell) size is denoted by alphabetical coding:

i.e.	Side length of cell (ft)	Enclosed area of cell (ft^2)
A	10,000	10^8
B	3,160	10^7
C	1,000	10^6

D	316	10^5
E	100	10^4

3) Pre-plot and sample positions were determined using a Decca minifix radionavigation system and were converted to U.T.M. and geographic coordinates, using computer subroutines F0020 and B51211 obtained from the Canadian Hydrographic Service, at CCIW.

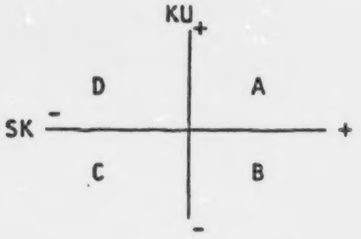
4) Date - year, month, day sample was obtained.

5) Depth - depth of water in metres obtained from a Kelvin Hughes MS26F (30 KH) echo sounder and corrected to chart datum.

6) SK-KU Sector (ref. 3) - this is a code related to the values of skewness (SK) and kurtosis (KU) (moment measures from total sample distribution in Table 2) and the presence or absence of gravel-size material (Table 3).

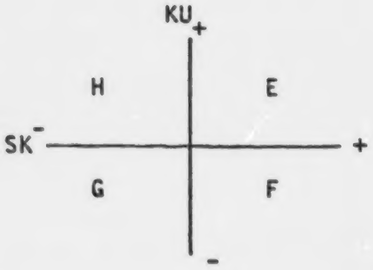
NO GRAVEL

A	$SK \geq 0$	$KU \geq 0$
B	$SK \geq 0$	$KU < 0$
C	$SK < 0$	$KU < 0$
D	$SK < 0$	$KU \geq 0$



WITH GRAVEL

E	$SK \geq 0$	$KU \geq 0$
F	$SK \geq 0$	$KU < 0$
G	$SK < 0$	$KU < 0$
H	$SK < 0$	$KU \geq 0$



7) Modes - modes in the gravel and sand particle size frequency distributions are listed in primary and secondary associations, in phi units;

- a zero value means there is no mode

Table 2 - Statistical treatment of particle size analyses

1) Station number
2) Columns 2 to 5 are moment measures on total sample distribution using the Sedan computer program (ref. 4)
3) Columns 6 to 9 are graphic statistics on total sample distribution using the Sizdist computer program (ref. 5).
4) Columns 10 to 13 are moment measures on gravel and sand portion, only, using the Sizdist computer program

Size analyses were made by: 1/4 phi interval sieving of gravel and sand, and the use of short pipette analysis on the fine fraction which gives only two data points for silt and clay.

In addition, there is an open-ended distribution for the fines. Sedan equally divides the silt into four classes and scales down clay by halfing it for each class interval until less than five percent remains. Sizdist sets a fine limit of 12 phi and clay decreases linearly from 8 to 12 phi. The percentiles for Folk's graphic statistics are determined using a straight line between data points.

Table 3

Size percentages and descriptive sediment classifications as determined by Sizdist program

Gravel	≤ -1.0 phi	or	> 2 mm
Sand	- 1.0 to 4.0 phi		2mm to 62.5μ
Silt	4.0 to 8.0 phi		62.5μ to 3.9μ
Clay	> 8.0 phi		< 3.9μ

Folk (GMS) - gravel, mud, sand diagram

(SCS) - sand, clay, silt diagram

Table 4 - Major elements

A geochemical subsample was obtained from the top $\overset{2}{3}$ cm of the Shipek sediment sample, and was prepared by being freeze dried, ground and pelletized. A comparison bulk subsample was obtained from the same Shipek sediment sample for the particle size analysis (Tables 2 and 3).

The major element oxides, in percent, were determined by X-ray fluorescence using a Phillips P.W. 1220C automatic spectrometer (Ref 6). A zero value means no analysis or data available.

Table 5 - Trace elements (Ref. 7)

A portion of the ground sample was used to determine the trace element concentrations in ppm (or μg/g), on a Techtron AA-5 atomic absorption spectrophotometer after hot concentrated HCℓ extraction.

Tests completed after these analyses have revealed that the results for some elements (marked *) are questionable and other elements (marked **) are highly questionable because of errors in the extraction method and iron interference.

Mercury was analyzed by Bondar-Clegg (Ottawa - Analytical Services)

SIZE STATISTICS ON TOTAL SAMPLE DISTRIBUTION / MOMENT MEASURES ON

/ MOMENT MEASURES / FOLK GRAPHIC STATISTICS/ DISTRIBUTION S + PHI

STN NO.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT
1	[illegible]	1.72	-0.33	-0.44	8.66	2.38	-0.24	0.65	3.85	0.00	0.00	0.00
2	7.75	1.79	-0.22	-0.83	8.09	2.64	-0.17	0.74	3.89	0.00	0.00	0.00
3	7.37	1.76	-0.27	-0.69	8.54	2.39	-0.19	0.80	3.88	0.00	0.00	0.00
4	7.37	1.74	-0.31	-0.54	8.65	2.36	-0.22	0.83	3.86	0.00	0.00	0.00
5	7.32	1.75	-0.26	-0.64	8.56	2.38	-0.21	0.81	3.88	0.00	0.00	0.00
6	7.54	1.81	-0.13	-1.01	7.63	2.64	-0.15	0.72	3.83	0.00	0.00	0.00
7	7.34	1.75	-0.32	-0.59	8.61	2.37	-0.21	0.82	3.88	0.00	0.00	0.00
8	7.33	1.79	-0.25	-0.77	8.07	2.57	-0.19	0.73	3.87	0.00	0.00	0.00
9	7.84	1.76	-0.26	-0.71	8.16	2.65	-0.21	0.75	3.88	0.00	0.00	0.00
10	7.79	1.73	-0.24	-0.78	8.35	2.49	-0.18	0.77	3.88	0.00	0.00	0.00
11	7.84	1.73	-0.29	-0.65	8.14	2.58	-0.22	0.74	3.85	0.00	0.00	0.00
12	7.86	1.77	-0.25	-0.71	8.51	2.40	-0.19	0.79	3.88	0.00	0.00	0.00
13	7.33	1.78	-0.25	-0.77	8.46	2.41	-0.17	0.76	3.88	0.00	0.00	0.00
14	7.51	2.19	-0.41	-0.12	8.22	2.78	-0.28	0.84	2.64	0.88	-0.23	-0.83
15	7.37	1.73	-0.32	-0.51	8.67	2.35	-0.22	0.84	3.85	0.00	0.00	0.00
16	7.35	1.75	-0.30	-0.58	8.61	2.37	-0.21	0.82	3.87	0.00	0.00	0.00
17	7.55	1.62	-0.18	-0.94	8.26	2.44	-0.11	0.75	3.88	0.00	0.00	0.00
18	[illegible]	1.75	-0.29	-0.62	8.45	2.49	-0.22	0.81	3.88	0.00	0.00	0.00
19	7.75	1.78	-0.22	-0.82	8.15	2.61	-0.18	0.75	3.89	0.00	0.00	0.00
20	7.83	1.77	-0.25	-0.73	8.44	2.45	-0.19	0.78	3.85	0.00	0.00	0.00
21	7.52	1.61	-0.12	-1.02	7.67	2.61	-0.05	0.73	3.86	0.00	0.00	0.00
22	7.86	1.76	-0.27	-0.58	8.10	2.59	-0.21	0.74	3.88	0.00	0.00	0.00
23	7.36	1.75	-0.29	-0.62	8.21	2.55	-0.23	0.76	3.83	0.00	0.00	0.00
24	7.73	1.78	-0.24	-0.78	8.35	2.49	-0.19	0.77	3.88	0.00	0.00	0.00
25	7.33	1.74	-0.35	-0.58	8.55	2.43	-0.22	0.82	3.88	0.00	0.00	0.00
26	[illegible]	1.77	-0.24	-0.76	8.42	2.45	-0.19	0.78	3.88	0.00	0.00	0.00
27	7.38	1.75	-0.28	-0.66	8.57	2.38	-0.20	0.80	3.89	0.00	0.00	0.00
28	7.55	1.57	-0.22	-0.84	8.29	2.50	-0.15	0.76	3.75	0.00	0.00	0.00
29	7.56	1.86	-0.17	-0.94	7.97	2.50	-0.02	0.74	3.85	0.00	0.00	0.00
30	7.54	1.62	-0.19	-0.93	8.07	2.59	-0.13	0.75	3.85	0.00	0.00	0.00
31	7.32	1.74	-0.29	-0.61	8.39	2.55	-0.23	0.81	3.88	0.00	0.00	0.00
32	[illegible]	1.62	-0.16	-0.97	8.03	2.58	-0.13	0.74	3.89	0.00	0.00	0.00
33	7.77	1.79	-0.23	-0.80	8.25	2.56	-0.19	0.77	3.85	0.00	0.00	0.00
34	7.76	1.78	-0.22	-0.82	8.34	2.48	-0.17	0.77	3.88	0.00	0.00	0.00
35	7.72	1.79	-0.21	-0.87	8.37	2.42	-0.15	0.76	3.86	0.00	0.00	0.00
36	[illegible]	1.73	-0.21	-0.85	8.33	2.47	-0.15	0.76	3.85	0.00	0.00	0.00
37	7.59	1.60	-0.19	-0.89	8.23	2.51	-0.14	0.75	3.83	0.00	0.00	0.00
38	7.55	1.60	-0.19	-0.90	8.05	2.62	-0.14	0.74	3.88	0.00	0.00	0.00
39	7.34	1.77	-0.26	-0.72	8.35	2.53	[illegible]	0.78	3.88	0.00	0.00	0.00
40	7.77	1.78	-0.23	-0.81	8.35	2.48	-0.17	0.77	3.87	0.00	0.00	0.00
41	7.77	1.78	-0.23	-0.81	8.31	2.51	-0.15	0.77	3.89	0.00	0.00	0.00
42	7.49	1.81	-0.11	-1.03	7.68	2.58	-0.14	0.74	3.88	0.00	0.00	0.00
43	[illegible]	1.73	-0.29	-0.53	8.37	2.35	-0.23	0.75	3.85	0.00	0.00	0.00
44	7.55	[illegible]	-0.16	-0.92	8.30	2.43	-0.12	0.75	3.83	0.00	0.00	0.00
45	[illegible]	1.79	-0.22	-0.85	8.25	2.51	-0.15	0.76	3.88	0.00	0.00	0.00
46	7.55	[illegible]	-0.16	-0.93	8.05	2.50	-0.13	0.74	3.87	0.00	0.00	0.00
47	[illegible]	[illegible]	-0.13	[illegible]	[illegible]	2.59	-0.06	0.74	3.88	0.00	0.00	0.00
48	7.37	1.73	-0.32	[illegible]	8.55	2.46	-0.24	0.83	3.85	0.00	0.00	0.00
49	7.56	[illegible]	-0.19	-0.93	8.25	2.48	-0.14	0.75	3.87	0.00	0.00	0.00
50	7.55	1.81	-0.15	-0.98	7.57	2.50	-0.09	0.74	3.89	0.00	0.00	0.00
51	7.58	1.65	-0.19	[illegible]	8.08	2.61	-0.14	0.74	3.85	0.00	0.00	0.00
52	[illegible]	1.77	-0.25	-0.73	8.36	2.50	-0.19	0.78	3.86	0.00	0.00	0.00
53	[illegible]	1.77	-0.25	-0.74	8.48	2.41	-0.19	0.76	3.88	0.00	0.00	0.00
54	[illegible]	1.81	-0.17	-0.94	8.08	2.57	-0.12	0.74	3.89	0.00	0.00	0.00
55	[illegible]	[illegible]	-0.21	-0.85	8.33	2.47	-0.16	0.76	3.88	0.00	0.00	0.00
56	[illegible]	1.77	-0.25	-0.74	8.45	2.43	-0.19	0.78	3.85	0.00	0.00	0.00
57	7.37	1.75	-0.27	-0.67	8.39	2.52	-0.22	0.79	3.88	0.00	0.00	0.00
58	7.79	1.76	-0.24	-0.76	8.34	2.50	-0.18	0.77	3.85	0.00	0.00	0.00
59	[illegible]	1.73	-0.22	-0.64	8.29	2.51	-0.17	0.76	3.88	0.00	0.00	0.00
60	7.37	[illegible]	[illegible]	-1.07	7.60	2.51	[illegible]	0.74	3.83	0.00	0.00	0.00
61	7.38	[illegible]	[illegible]	-1.06	[illegible]	2.59	-0.03	0.74	3.88	0.00	0.00	0.00
62	7.56	[illegible]	-0.16	-0.91	8.10	2.59	-0.14	0.75	3.88	0.00	0.00	0.00
63	[illegible]	[illegible]	-0.18	-0.92	7.95	2.64	-0.13	0.73	3.88	0.00	0.00	0.00
64	7.56	[illegible]	-0.16	-0.92	8.05	2.51	-0.13	0.74	3.88	0.00	0.00	0.00
65	7.57	[illegible]	-0.14	-0.99	7.97	2.59	-0.09	0.74	3.83	0.00	0.00	0.00
66	[illegible]	1.52	-0.09	-1.35	7.67	2.55	-0.01	0.74	3.85	0.00	0.00	0.00
67	[illegible]	[illegible]	[illegible]	[illegible]	7.69	[illegible]	[illegible]	0.74	3.88	0.00	0.00	0.00
68	7.59	1.81	-0.15	-0.97	7.92	2.63	-0.13	0.73	3.88	0.00	0.00	0.00
69	7.39	1.82	-0.17	[illegible]	7.77	2.55	-0.03	0.74	3.87	0.00	0.00	0.00
70	7.51	1.81	-0.12	-1.02	7.79	2.64	-0.04	0.72	3.85	0.00	0.00	0.00
STN NO.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT.

/ SIZE STATISTICS ON TOTAL SAMPLE DISTRIBUTION / MOMENT MEASURES ON
MOMENT MEASURES / FOLK GRAPHIC STATISTICS/ DISTRIBUTION ≤ 4 PHI

STN NO.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT
71	7.40	1.82	-0.08	-1.06	7.69	2.61	0.12	0.73	3.88	0.00	0.00	0.00
72	6.34	1.65	-0.03	-1.22	7.33	2.55	0.15	0.77	3.89	0.00	0.00	0.00
73	6.39	1.64	-0.01	-1.21	7.49	2.43	0.17	0.78	3.87	0.00	0.00	0.00
74	7.27	1.81	-0.02	-1.07	7.60	2.55	0.09	0.75	3.85	0.00	0.00	0.00
75	7.36	1.82	-0.06	-1.07	7.48	2.65	0.05	0.72	3.88	0.00	0.00	0.00
76	7.35	1.82	-0.05	-1.07	7.69	2.57	0.04	0.74	3.88	0.00	0.00	0.00
77	7.26	1.81	-0.02	-1.07	7.67	2.50	0.03	0.75	3.83	0.00	0.00	0.00
78	7.39	1.82	-0.07	-1.06	7.75	2.57	0.03	0.74	3.88	0.00	0.00	0.00
79	6.39	1.64	-0.01	-1.21	7.40	2.48	0.17	0.78	3.89	0.00	0.00	0.00
8	6.91	1.62	0.03	-1.17	7.27	2.44	0.20	0.82	3.88	0.00	0.00	0.00
81	7.27	1.81	-0.03	-1.07	7.39	2.53	0.14	0.73	3.85	0.00	0.00	0.00
82	7.17	1.80	0.01	-1.06	7.58	2.47	0.13	0.76	3.87	0.00	0.00	0.00
83	7.36	1.81	-0.14	-1.03	8.05	2.53	-0.09	0.74	3.87	0.00	0.00	0.00
84	7.34	1.82	-0.05	-1.07	7.46	2.65	0.07	0.72	3.89	0.00	0.00	0.00
85	6.32	1.65	-0.02	-1.22	7.41	2.51	0.15	0.76	3.87	0.00	0.00	0.00
86	7.15	1.80	0.02	-1.05	7.57	2.45	0.15	0.76	3.89	0.00	0.00	0.00
87	6.79	1.62	0.03	-1.16	7.32	2.40	0.21	0.82	3.89	0.00	0.00	0.00
88	6.96	1.65	-0.03	-1.23	7.50	2.49	0.14	0.77	3.88	0.00	0.00	0.00
89	6.32	1.62	-0.02	-1.18	7.31	2.43	0.21	0.81	3.88	0.00	0.00	0.00
9	6.39	1.64	-0.01	-1.21	7.43	2.46	0.17	0.78	3.85	0.00	0.00	0.00
91	7.47	1.82	-0.10	-1.04	8.04	2.46	-0.03	0.74	3.87	0.00	0.00	0.00
92	7.47	1.82	-0.10	-1.04	7.67	2.57	-0.02	0.74	3.87	0.00	0.00	0.00
93	7.36	1.82	-0.07	-1.07	7.86	2.49	0.03	0.74	3.87	0.00	0.00	0.00
94	7.32	1.81	-0.04	-1.07	7.80	2.48	0.07	0.74	3.88	0.00	0.00	0.00
95	7.27	1.81	-0.02	-1.07	7.59	2.55	0.09	0.75	3.85	0.00	0.00	0.00
96	7.22	1.81	-0.00	-1.07	7.58	2.51	0.11	0.75	3.88	0.00	0.00	0.00
97	[illegible]	1.66	-0.05	-1.23	7.41	2.58	0.12	0.75	3.88	0.00	0.00	0.00
98	6.95	1.65	-0.04	-1.23	7.53	2.48	0.14	0.76	3.89	0.00	0.00	0.00
99	7.52	1.81	-0.12	-1.01	7.90	2.60	-0.05	0.74	3.87	0.00	0.00	0.00
100	7.49	1.81	-0.11	-1.03	7.81	2.52	-0.04	0.73	3.87	0.00	0.00	0.00
101	7.34	1.82	-0.08	-1.06	7.58	2.65	0.03	0.72	3.88	0.00	0.00	0.00
102	7.32	1.81	-0.04	-1.07	7.71	2.53	0.05	0.74	3.85	0.00	0.00	0.00
103	6.95	1.65	-0.03	-1.22	7.22	2.60	0.15	0.75	3.89	0.00	0.00	0.00
104	7.18	1.80	0.01	-1.06	7.54	2.51	0.13	0.76	3.89	0.00	0.00	0.00
105	6.36	1.65	-0.04	-1.23	7.50	2.50	0.14	0.76	3.88	0.00	0.00	0.00
106	7.31	1.81	-0.04	-1.07	7.67	2.55	0.07	0.75	3.85	0.00	0.00	0.00
107	7.59	1.81	-0.16	-0.97	8.08	2.55	-0.10	0.74	3.89	0.00	0.00	0.00
108	7.59	1.81	-0.15	-0.97	8.00	2.59	-0.10	0.74	3.89	0.00	0.00	0.00
109	7.31	1.81	-0.04	-1.07	7.74	2.51	0.05	0.74	3.86	0.00	0.00	0.00
110	7.40	1.83	-0.05	-1.06	7.82	2.54	[illegible]	0.74	3.88	0.00	0.00	0.00
111	7.23	1.81	-0.01	-1.07	7.60	2.52	0.10	0.75	3.89	0.00	0.00	0.00
112	7.22	1.81	-0.01	-1.07	7.53	2.54	0.11	0.75	3.87	0.00	0.00	0.00
113	7.31	1.81	-0.04	-1.07	7.62	2.57	0.07	0.74	3.85	0.00	0.00	0.00
114	7.25	1.81	-0.02	-1.07	7.66	2.51	0.10	0.75	3.85	0.00	0.00	0.00
115	7.51	1.81	-0.16	-0.96	8.19	2.47	-0.10	0.75	3.89	0.00	0.00	0.00
116	7.57	1.83	-0.14	-1.03	7.62	2.72	-0.04	0.69	3.88	0.00	0.00	0.00
117	7.44	1.82	-0.11	-1.05	7.66	2.55	-0.01	0.74	3.85	0.00	0.00	0.00
118	7.47	1.82	-0.11	-1.04	7.91	2.54	-0.03	0.74	3.85	0.00	0.00	0.00
119	7.21	1.81	-0.01	-1.07	7.58	2.50	0.12	0.75	3.83	0.00	0.00	0.00
120	7.28	1.81	-0.03	-1.07	7.57	2.57	0.08	0.74	3.85	0.00	0.00	0.00
121	7.13	1.80	0.02	-1.06	7.52	2.43	0.14	0.76	3.88	0.00	0.00	0.00
122	6.94	1.65	-0.03	-1.22	7.62	2.42	0.15	0.76	3.88	0.00	0.00	0.00
123	7.44	1.82	-0.09	-1.05	7.95	2.49	-0.01	0.74	3.88	0.00	0.00	0.00
124	7.49	1.82	-0.11	-1.03	7.69	2.66	-0.02	0.72	3.88	0.00	0.00	0.00
125	7.48	1.81	-0.11	-1.03	8.01	2.49	-0.03	0.74	3.88	0.00	0.00	0.00
126	7.44	1.83	-0.06	-1.05	7.98	2.47	-0.01	0.74	3.85	0.00	0.00	0.00
127	7.22	1.81	-0.01	-1.07	7.60	2.50	0.11	0.75	3.88	0.00	0.00	0.00
128	6.75	1.74	-0.04	-1.18	7.44	2.52	0.15	0.77	3.75	0.00	0.00	0.00
129	6.39	1.65	-0.05	-1.23	7.45	2.55	0.12	0.76	3.89	0.00	0.00	0.00
130	6.70	1.58	-0.07	-1.09	6.65	2.43	0.23	0.91	3.86	0.00	0.00	0.00
131	7.46	1.83	-0.10	-1.04	7.96	2.53	-0.02	0.74	3.87	0.00	0.00	0.00
132	7.46	1.83	-0.11	-1.04	7.69	2.55	-0.02	0.74	3.88	0.00	0.00	0.00
133	7.45	1.82	-0.10	-1.04	7.61	2.59	-0.01	0.74	3.83	0.00	0.00	0.00
134	7.35	1.82	-0.07	-1.06	7.62	2.62	0.04	0.73	3.86	0.00	0.00	0.00
135	6.86	1.63	0.01	-1.19	7.31	2.48	0.13	0.81	3.88	0.00	0.00	0.00
136	6.79	1.65	0.04	-1.16	7.21	2.44	0.21	0.83	3.85	0.00	0.00	0.00
137	6.36	1.65	-0.03	-1.23	7.54	2.47	0.14	0.77	3.87	0.00	0.00	0.00
138	6.54	1.63	0.01	-1.19	7.20	2.51	0.16	0.80	3.88	0.00	0.00	0.00
139	7.45	1.82	-0.10	-1.04	7.67	2.55	-0.01	0.74	3.88	0.00	0.00	0.00
140	7.41	1.82	-0.08	-1.06	7.76	2.58	0.01	0.74	3.89	0.00	0.00	0.00
STN NO.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT

SIZE STATISTICS ON TOTAL SAMPLE DISTRIBUTION

STN NO.	MOMENT MEASURES				FOLK GRAPHIC STATISTICS				MOMENT MEASURES ON DISTRIBUTION S - PHI			
	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT
141	6.25	1.92	-0.02	-0.86	6.71	2.52	0.13	0.98	3.26	0.57	-0.80	2.42
142	1.70	1.39	0.65	6.27	1.65	1.06	-0.19	2.31	1.48	1.01	-0.62	1.90
143	3.37	1.35	1.26	6.41	2.65	1.18	0.64	4.47	2.64	0.43	-0.72	9.30
144	5.43	1.82	0.02	-0.39	5.91	2.41	0.22	0.91	3.25	0.71	-0.91	2.79
145	5.54	1.94	-0.08	-0.75	6.17	2.56	0.17	0.94	2.98	0.91	-1.48	10.90
146	4.78	2.27	0.25	-0.63	4.64	2.42	0.50	1.11	2.95	0.89	-0.57	1.36
147	5.25	2.12	0.19	-0.91	5.15	2.35	0.33	1.32	3.06	0.63	-0.58	1.66
148	2.27	1.08	1.77	15.23	2.12	0.53	0.35	1.33	2.07	0.49	-0.03	3.20
149	3.00	1.73	0.98	2.80	2.81	1.49	0.71	3.72	2.28	0.45	0.16	1.52
150	3.06	1.58	1.09	3.83	2.62	1.12	0.52	3.43	2.46	0.42	0.04	1.69
151	2.35	1.54	0.88	1.69	2.66	1.50	0.77	3.11	2.12	0.43	0.50	2.32
152	5.53	2.02	0.13	-0.63	5.48	2.22	0.25	0.92	3.27	0.88	-0.93	3.11
153	5.54	1.79	-0.04	-0.85	5.77	2.27	0.13	0.96	3.11	0.75	-0.84	1.82
154	3.72	2.17	0.22	-0.17	3.93	2.57	0.35	1.23	2.45	1.19	-0.52	1.27
155	3.73	2.14	0.37	-0.21	3.88	2.27	0.50	1.27	2.58	0.65	-0.57	1.76
156	2.91	1.63	1.07	3.69	2.98	1.62	0.77	3.34	2.29	0.44	0.28	2.13
157	2.88	1.55	1.15	4.44	2.42	1.04	0.54	3.75	2.30	0.43	0.07	1.84
158	2.92	1.23	1.42	9.33	2.69	0.97	0.33	3.94	2.59	0.47	-0.77	6.28
159	3.15	1.55	1.02	3.53	2.59	1.39	0.47	3.69	2.56	0.52	-0.38	1.33
160	5.45	2.21	-0.01	-0.38	5.55	2.50	0.21	0.98	3.01	1.13	-1.41	3.95
161	5.29	1.93	0.08	-0.69	5.31	2.17	0.34	0.92	3.26	0.71	-1.47	11.38
162	3.59	1.96	0.33	0.58	3.94	2.27	0.50	1.43	2.62	1.04	-1.00	5.51
163	3.38	1.92	0.39	0.62	3.46	1.93	0.32	1.57	2.52	1.05	-0.56	2.09
164	3.10	1.57	1.02	3.18	2.70	1.36	0.67	3.41	2.32	0.45	0.16	1.50
165	3.01	1.66	1.01	3.13	2.66	1.28	0.66	3.30	2.34	0.46	0.18	1.56
166	3.20	1.45	1.17	4.65	2.62	1.03	0.59	4.37	2.67	0.35	0.18	2.03
167	3.25	1.55	1.04	3.37	2.64	1.12	0.61	4.59	2.62	0.37	0.06	2.01
168	5.34	1.90	0.01	-0.87	5.56	2.28	0.18	0.98	3.19	0.79	-0.78	1.45
169	5.03	1.87	0.10	-0.71	5.29	2.20	0.35	0.98	3.29	0.76	-1.13	5.56
170	4.28	1.99	0.34	-0.38	4.32	2.41	0.51	1.10	2.78	0.85	-0.59	1.55
171	3.32	1.96	0.27	0.76	3.41	2.06	0.23	2.04	2.42	1.23	-0.85	3.06
172	2.95	1.56	1.10	3.99	2.53	1.08	0.59	3.51	2.36	0.43	0.32	1.83
173	3.04	1.59	0.99	2.96	2.55	1.15	0.62	3.71	2.33	0.43	0.16	1.81
174	2.95	1.32	1.35	7.42	2.70	1.05	0.47	3.92	2.57	0.45	-0.46	5.25
175	3.16	1.39	1.04	3.35	2.76	1.15	0.58	3.58	2.55	0.40	0.25	1.39
176	5.30	2.03	0.14	-0.69	5.45	2.25	0.32	0.96	3.32	0.76	-1.16	5.53
177	5.31	1.72	0.04	-0.95	5.48	2.06	0.21	0.86	3.25	0.65	-1.09	4.32
178	3.35	2.15	0.28	-0.51	3.83	2.50	0.44	1.13	2.47	1.10	-0.44	2.46
179	3.36	1.82	0.38	1.15	3.48	1.85	0.37	2.17	2.61	1.05	-0.96	3.41
180	3.01	1.75	0.95	2.85	3.21	1.55	0.77	2.06	2.33	0.47	0.16	1.52
181	2.51	1.59	1.64	13.65	2.33	1.53	0.20	1.57	2.28	0.49	-0.62	7.42
182	[illegible]	1.47	1.42	5.27	2.63	1.08	0.52	3.54	2.57	0.4	0.26	1.21
183	2.52	1.93	1.55	13.61	2.53	1.45	0.53	1.37	2.47	0.42	-0.35	4.52
184	5.53	2.10	0.01	-0.65	5.61	2.42	0.24	0.95	3.21	0.89	-0.31	1.97
185	5.22	1.92	0.08	-0.62	5.39	2.31	0.35	0.86	3.24	0.78	-1.26	7.64
186	3.67	2.14	0.31	-0.11	3.69	2.1	0.40	1.26	2.55	0.99	-0.63	2.17
187	3.58	2.05	0.31	-0.19	3.74	2.17	0.41	1.17	2.55	0.98	-0.53	1.37
188	3.04	1.67	0.99	2.94	2.69	1.31	0.65	3.12	2.35	0.48	0.15	1.46
189	3.22	1.85	0.63	1.61	3.30	1.97	0.76	2.73	2.34	0.51	0.26	1.18
190	2.95	1.50	1.12	3.95	2.47	1.05	0.57	3.42	2.34	0.41	0.35	1.45
191	3.11	1.54	1.23	4.36	2.63	1.17	0.50	3.18	2.45	0.44	0.17	1.45
192	5.41	2.03	0.17	-0.79	5.32	2.21	0.30	0.92	3.27	0.67	-0.96	3.23
193	5.23	2.12	0.13	-0.66	5.33	2.33	0.33	1.00	3.21	0.32	-1.03	4.58
194	3.21	1.99	0.41	0.58	3.24	2.08	0.32	1.65	2.71	1.14	-0.53	2.12
195	2.35	1.72	1.47	2.50	2.43	1.52	0.55	1.76	2.12	1.17	-0.55	1.48
196	2.71	1.45	1.32	6.52	2.36	1.11	0.48	3.76	2.23	0.46	-0.22	1.56
197	3.14	1.72	0.91	2.26	3.29	1.39	0.75	2.75	2.38	0.44	0.08	1.57
198	2.73	1.33	1.36	7.22	2.42	1.05	0.45	3.32	2.31	0.45	0.11	1.92
199	2.35	1.3	1.39	7.23	2.71	1.10	0.55	3.67	2.55	0.36	0.14	1.36
200	4.90	1.93	0.04	-0.45	5.10	2.39	0.37	1.07	3.07	0.96	-0.98	3.74
201	4.73	1.96	0.13	-0.71	5.10	2.35	0.35	1.03	3.06	0.83	-0.61	2.33
202	3.45	2.13	0.24	[illegible]	3.57	2.26	0.29	1.34	2.36	1.22	-0.65	1.83
203	3.31	1.72	0.65	4.01	2.08	1.37	0.55	3.09	1.62	1.05	-1.01	3.39
204	3.75	1.41	1.28	5.19	2.42	1.04	0.51	3.30	2.29	0.46	0.19	1.53
205	2.36	1.55	0.88	4.99	2.67	1.25	0.45	4.14	2.35	0.79	-1.73	17.26
206	1.32	1.72	0.65	3.87	1.76	1.41	0.10	3.48	1.49	1.04	-0.75	2.73
207	2.37	1.28	1.15	4.5	2.51	1.10	0.44	4.9	2.41	0.45	-1.44	5.69
208	4.25	2.18	0.05	-0.51	4.37	2.56	0.30	1.01	2.67	1.19	-0.61	1.77
209	3.36	2.09	0.32	0.07	3.51	2.22	0.35	1.26	2.30	1.01	-0.5	1.47
210	3.03	1.3	0.77	1.29	2.90	1.88	0.65	2.11	2.07	0.64	0.23	1.33
STN NO.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT.

SIZE STATISTICS ON TOTAL SAMPLE DISTRIBUTION / MOMENT MEASURES ON
/ MOMENT MEASURES / FOLK GRAPHIC STATISTICS/ DISTRIBUTION ≤ 4 PHI

STN NO.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT.
211	2.26	0.87	1.67	15.31	2.18	0.59	0.17	1.41	2.13	0.51	[illegible]	0.62
212	2.38	0.92	2.08	20.55	2.24	0.42	0.30	1.18	2.22	0.39	0.22	2.22
213	6.36	[illegible]	0.07	-0.97	6.41	2.51	0.24	0.93	2.92	0.79	-0.70	2.35
214	4.26	1.93	0.25	-0.33	4.49	2.25	0.48	1.13	2.99	0.66	-0.76	2.26
215	[illegible]	2.27	0.57	0.18	3.65	2.08	0.55	1.66	2.63	0.68	-0.22	-0.37
216	2.95	1.46	1.19	5.44	2.62	1.13	0.36	3.28	2.48	0.51	-0.19	0.57
217	2.71	0.93	1.77	15.51	2.55	0.44	0.00	1.24	2.53	0.41	-0.14	1.60
218	2.75	0.96	1.79	15.84	2.60	0.48	0.12	1.61	2.57	0.42	-0.32	3.72
219	1.04	2.62	0.74	2.01	0.59	1.63	0.28	1.23	0.48	1.19	0.18	-0.51
220	[illegible]	2.26	0.93	2.06	2.20	1.03	0.53	4.22	[illegible]	0.41	0.16	2.49
221	5.26	1.92	0.05	-1.05	5.66	2.46	0.21	0.91	3.13	0.63	-0.61	0.89
222	4.76	1.89	0.23	-0.87	5.08	2.34	0.41	0.97	3.17	0.63	-0.61	1.06
223	4.01	1.99	0.54	-0.16	4.32	2.46	0.75	1.07	2.76	0.48	-0.25	0.89
224	[illegible]	1.57	1.05	3.77	2.63	1.21	0.41	3.11	2.44	0.51	-0.11	0.72
225	[illegible]	1.26	1.54	9.86	2.22	0.73	0.35	2.37	2.17	0.42	0.08	1.21
226	2.65	1.20	1.72	12.59	2.41	0.49	0.23	1.53	2.37	0.40	0.02	1.23
227	1.53	2.88	0.40	-0.43	1.76	3.04	0.38	0.93	0.31	1.55	0.22	-1.00
228	2.32	2.16	0.49	1.33	1.68	2.04	0.07	2.17	1.26	1.34	-0.51	0.73
229	[illegible]	1.86	0.15	-0.93	5.29	[illegible]	0.31	0.35	3.19	0.64	-0.59	1.71
230	4.92	1.93	0.17	-1.00	5.25	2.42	0.34	0.96	3.12	0.65	-0.55	1.27
231	3.14	1.68	0.95	2.72	3.05	1.50	0.65	3.18	2.45	0.49	[illegible]	0.65
232	2.93	1.25	1.39	8.06	2.68	0.97	0.40	[illegible]	2.57	0.47	-0.17	1.39
233	[illegible]	1.42	0.77	5.66	1.83	1.05	-0.14	[illegible]	1.74	0.97	[illegible]	1.13
234	2.72	1.21	1.58	10.40	2.45	0.54	0.29	1.73	2.40	0.42	-0.04	1.63
235	2.33	1.53	0.97	5.08	2.14	1.31	0.51	3.68	1.85	0.75	-1.06	9.36
236	[illegible]	1.95	0.64	2.64	1.84	1.62	0.14	3.50	1.51	1.08	-0.62	1.68
237	[illegible]	1.92	0.13	-0.96	5.20	2.42	0.37	0.97	3.16	0.66	-0.50	[illegible]
238	4.73	1.92	0.24	-0.85	5.00	2.38	0.45	0.95	3.11	0.65	-0.62	1.11
239	4.32	2.27	0.29	-1.04	4.82	2.92	0.52	0.84	2.43	0.61	-0.22	0.18
240	3.64	1.93	0.63	0.35	3.95	2.41	0.75	1.26	2.53	0.52	-0.26	0.72
241	[illegible]	1.54	1.07	[illegible]	3.26	1.44	0.61	3.44	2.92	0.42	-0.05	0.52
242	[illegible]	1.07	1.70	14.10	2.09	0.72	0.26	1.69	2.03	0.52	0.14	0.33
243	2.30	2.34	0.47	0.53	2.35	2.50	0.34	2.02	1.34	1.25	-0.39	0.27
244	[illegible]	2.67	0.36	-0.43	2.45	2.87	0.40	0.97	1.02	1.32	-0.01	-0.60
245	[illegible]	1.69	[illegible]	[illegible]	5.49	2.39	0.26	0.31	3.18	0.62	-0.79	2.54
246	4.33	[illegible]	0.23	[illegible]	5.15	2.38	0.40	0.35	3.19	0.62	-0.57	1.61
247	[illegible]	2.17	[illegible]	-0.75	4.48	2.72	0.68	0.89	2.59	0.53	-0.14	0.55
248	3.36	1.76	0.83	1.87	3.25	1.76	0.64	3.06	2.58	0.55	-0.19	0.46
249	[illegible]	1.23	1.56	[illegible]	2.52	1.55	0.30	[illegible]	2.48	0.37	[illegible]	1.56
250	[illegible]	1.01	1.28	13.71	2.09	0.68	-0.11	1.27	2.06	0.67	-0.35	1.66
251	2.09	2.82	0.37	-0.59	2.20	[illegible]	0.43	0.87	0.67	1.42	0.19	-0.74
252	[illegible]	[illegible]	0.44	[illegible]	2.05	2.62	0.34	1.19	[illegible]	1.37	[illegible]	-0.68
253	[illegible]	[illegible]	0.17	[illegible]	[illegible]	2.46	0.31	[illegible]	[illegible]	0.64	[illegible]	1.37
254	4.91	1.53	0.20	-0.94	5.24	2.37	0.37	0.96	[illegible]	0.62	-0.58	1.61
255	3.97	[illegible]	0.63	0.24	4.25	2.44	0.79	1.13	2.74	0.43	-0.36	1.04
256	[illegible]	1.59	[illegible]	3.84	2.51	1.24	0.36	2.62	2.32	0.59	[illegible]	[illegible]
257	[illegible]	[illegible]	1.69	11.83	2.57	0.52	0.33	2.35	2.52	0.35	[illegible]	2.19
258	[illegible]	[illegible]	1.51	11.97	2.46	0.62	0.13	2.15	2.41	0.50	-0.78	6.46
259	1.38	2.46	0.51	0.23	1.96	2.64	0.40	1.22	0.87	[illegible]	0.06	-0.61
260	[illegible]	2.26	0.54	1.21	1.26	2.18	0.15	1.76	0.85	1.35	-0.17	-0.38
261	[illegible]	1.92	[illegible]	-0.75	6.76	2.54	0.21	0.92	3.23	0.35	-1.77	16.23
262	[illegible]	1.99	0.07	-1.02	6.17	2.57	0.22	0.95	3.33	0.54	-1.06	4.62
263	[illegible]	1.39	1.16	5.14	2.81	1.09	0.47	[illegible]	2.64	0.48	-0.06	1.11
264	[illegible]	1.73	.93	2.57	2.77	1.47	0.61	2.96	2.33	0.52	[illegible]	0.51
265	[illegible]	1.62	1.18	7.47	1.93	1.48	0.29	3.41	[illegible]	0.81	-0.69	4.59
266	[illegible]	[illegible]	.67	7.11	1.94	0.35	-0.25	1.47	1.85	0.92	[illegible]	1.55
267	2.39	[illegible]	0.27	-0.87	2.39	3.13	0.35	0.62	0.75	1.49	0.12	-0.95
268	2.77	1.76	0.96	2.76	2.19	1.26	0.44	3.22	[illegible]	0.56	0.15	0.65
269	[illegible]	1.57	[illegible]	-1.07	[illegible]	2.38	0.23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
270	[illegible]	[illegible]	[illegible]	-0.96	6.53	2.79	0.14	0.92	3.03	0.68	-0.57	0.77
271	[illegible]	1.94	0.17	[illegible]	5.55	2.55	0.33	0.88	3.20	0.55	-0.71	2.78
272	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
273	[illegible]	1.14	[illegible]	[illegible]	[illegible]	0.37	0.11	1.25	2.40	0.36	0.06	1.78
274	2.63	0.75	2.10	26.50	2.56	0.48	0.13	1.39	2.54	0.44	-0.02	1.41
275	2.08	[illegible]	0.84	6.69	1.98	1.22	0.27	3.11	1.75	0.94	-1.01	5.55
276	2.59	1.27	1.65	10.79	2.28	1.40	0.43	1.53	2.25	0.36	0.40	[illegible]
277	5.32	1.73	0.14	[illegible]	5.76	2.22	0.17	0.94	3.77	0.49	[illegible]	4.83
278	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
279	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
280	2.96	[illegible]	1.63	12.71	2.76	0.51	[illegible]	1.24	2.73	0.47	-0.22	0.93
281	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00	0.00
STN NO.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT.	MEAN	STDEV.	SKEW.	KURT.

STN NO.	CELL SIZE	U.T.M. NORTHING	U.T.M. EASTING	LATITUDE D	LATITUDE M	LATITUDE S	LONGITUDE D	LONGITUDE M	LONGITUDE S	DATE YYMMDD	DEPTH METRE	SK-KU SECTOR	MODES 1	MODES 2
1	A	4801646.	643062.	43	21	20.95	79	13	24.82	691110	104.8	C	0.0	0.0
2	A	4802750.	646915.	43	21	41.70	79	11	12.88	691110	105.8	C	0.0	0.0
3	A	4803044.	649894.	43	22	2.07	79	9	0.05	691104	104.8	C	0.0	0.0
4	A	4803754.	652856.	43	22	22.91	79	6	47.87	691104	104.8	C	0.0	0.0
5	A	4804452.	655825.	43	22	43.34	79	4	35.22	691104	105.8	C	0.0	0.0
6	B	4800865.	645205.	43	20	54.78	79	12	30.37	691110	101.8	C	0.0	0.0
7	B	4801084.	646040.	43	21	1.30	79	11	53.09	691110	101.8	C	0.0	0.0
8	B	4801574.	648162.	43	21	15.66	79	10	18.38	691108	102.8	C	0.0	0.0
9	B	4801801.	649104.	43	21	22.36	79	9	36.36	691108	102.8	C	0.0	0.0
10	B	4802265.	651121.	43	21	35.93	79	8	6.34	691105	101.8	C	0.0	0.0
11	B	4802497.	652060.	43	21	42.78	79	7	24.41	691105	99.8	C	0.0	0.0
12	B	4802961.	654092.	43	21	56.98	79	5	53.68	691103	100.8	C	0.0	0.0
13	B	4803199.	655024.	43	22	3.33	79	5	12.06	691103	101.8	C	0.0	0.0
14	C	4800624.	645582.	43	20	46.71	79	12	13.88	691123	100.9	C	0.0	0.0
15	C	4800698.	645899.	43	20	48.89	79	11	59.71	691123	100.9	C	0.0	0.0
16	C	4801331.	648549.	43	21	7.51	79	10	1.45	691109	102.8	C	0.0	0.0
17	C	4801401.	648868.	43	21	9.55	79	9	47.23	691109	101.8	C	0.0	0.0
18	C	4802027.	651525.	43	21	27.92	79	7	48.64	691105	100.8	C	0.0	0.0
19	C	4802072.	651759.	43	21	29.21	79	7	38.18	691105	99.8	C	0.0	0.0
20	C	4802723.	654463.	43	21	46.30	79	5	36.14	691103	98.8	C	0.0	0.0
21	C	4802801.	654798.	43	21	50.62	79	5	22.61	691103	99.8	C	0.0	0.0
22	D	4800555.	645732.	43	20	44.39	79	12	7.27	691123	100.9	C	0.0	0.0
23	D	4800572.	645814.	43	20	44.85	79	12	3.61	691123	100.9	C	0.0	0.0
24	D	4801240.	648693.	43	21	4.77	79	9	55.11	691110	101.8	C	0.0	0.0
25	D	4801262.	648782.	43	21	5.14	79	9	51.18	691109	101.8	C	0.0	0.0
26	D	4801949.	651653.	43	21	25.31	79	7	43.03	691105	99.8	C	0.0	0.0
27	D	4801965.	651740.	43	21	25.77	79	7	39.14	691105	99.8	C	0.0	0.0
28	D	4802649.	654520.	43	21	45.81	79	5	30.57	691103	98.8	C	0.0	0.0
29	D	4802667.	654713.	43	21	46.34	79	5	26.45	691103	98.8	C	0.0	0.0
30	E	4800524.	645763.	43	20	43.35	79	12	5.90	691123	100.9	C	0.0	0.0
31	E	4800543.	645799.	43	20	43.92	79	12	4.28	691123	100.9	C	0.0	0.0
32	E	4801229.	648731.	43	21	4.08	79	9	53.48	691110	101.8	C	0.0	0.0
33	E	4801243.	648763.	43	21	4.51	79	9	52.02	691109	101.8	C	0.0	0.0
34	E	4801927.	651681.	43	21	24.44	79	7	41.80	691105	99.8	C	0.0	0.0
35	E	4801935.	651715.	43	21	24.83	79	7	40.22	691105	99.8	C	0.0	0.0
36	E	4802620.	654667.	43	21	45.12	79	5	28.52	691104	98.8	C	0.0	0.0
37	E	4802635.	654693.	43	21	45.32	79	5	27.37	691103	98.8	C	0.0	0.0
38	E	4800495.	645769.	43	20	42.38	79	12	5.67	691123	100.9	C	0.0	0.0
39	E	4800501.	645801.	43	20	42.58	79	12	4.23	691123	100.9	C	0.0	0.0
40	E	4801196.	648736.	43	21	3.02	79	9	53.29	691110	101.8	C	0.0	0.0
41	E	4801202.	648765.	43	21	3.19	79	9	51.98	691109	101.8	C	0.0	0.0
42	E	4801892.	651697.	43	21	23.44	79	7	41.14	691105	99.8	C	0.0	0.0
43	E	4801901.	651723.	43	21	23.69	79	7	39.95	691105	99.8	C	0.0	0.0
44	E	4802588.	654667.	43	21	43.81	79	5	28.56	691104	97.8	C	0.0	0.0
45	E	4802600.	654695.	43	21	44.16	79	5	27.31	691103	97.8	C	0.0	0.0
46	D	4800462.	645745.	43	20	41.33	79	12	6.78	691123	100.9	C	0.0	0.0
47	D	4800478.	645934.	43	20	41.81	79	12	2.83	691123	100.9	C	0.0	0.0
48	D	4801167.	648711.	43	21	1.38	79	9	54.41	691110	101.8	C	0.0	0.0
49	D	4801182.	648801.	43	21	2.53	79	9	50.42	691109	101.8	C	0.0	0.0
50	D	4801857.	651666.	43	21	22.19	79	7	42.53	691108	98.8	C	0.0	0.0
51	D	4801871.	651767.	43	21	22.71	79	7	38.04	691105	98.8	C	0.0	0.0
52	D	4802558.	654645.	43	21	42.89	79	5	29.55	691104	98.8	C	0.0	0.0
53	D	4802582.	654732.	43	21	43.58	79	5	25.68	691103	97.8	C	0.0	0.0
54	C	4800319.	645661.	43	20	36.78	79	12	10.65	691123	100.9	C	0.0	0.0
55	C	[illegible]	645967.	43	20	39.22	79	11	56.99	691123	100.9	C	0.0	0.0
56	C	[illegible]	648625.	43	20	57.79	79	9	58.39	691110	100.8	C	0.0	0.0
57	C	48011[illegible].	648925.	43	21	0.02	79	9	44.98	691109	100.8	C	0.0	0.0
58	C	4801730.	651591.	43	21	18.27	79	7	45.99	691108	97.8	C	0.0	0.0
59	C	4801730.	651902.	43	21	20.26	79	7	32.10	691105	97.8	C	0.0	0.0
60	C	[illegible]	654574.	43	21	38.51	79	5	32.57	691104	97.8	C	0.0	0.0
61	C	48025[illegible]1.	654863.	43	21	40.52	79	5	19.93	691103	97.8	C	0.0	0.0
62	B	4799331.	645414.	43	20	24.37	79	12	21.38	691122	98.9	C	0.0	0.0
63	B	4800140.	646353.	43	20	30.79	79	11	40.08	691122	98.9	C	0.0	0.0
64	B	4800647.	646784.	43	20	45.36	79	10	9.45	691108	98.8	C	0.0	0.0
65	B	4800961.	649314.	43	20	51.76	79	9	27.95	691108	97.8	C	0.0	0.0
66	B	4801320.	651344.	43	21	5.15	79	7	57.35	691108	95.8	C	0.0	0.0
67	B	4801559.	652286.	43	21	12.21	79	7	15.30	691105	95.8	C	0.0	0.0
68	B	48020[illegible]4.	654326.	43	21	26.1[illegible]	79	5	44.26	691104	96.8	C	0.0	0.0
69	B	4802263.	655260.	43	21	32.83	79	5	2.56	691103	95.8	C	0.0	0.0
70	A	479867[illegible].	644640.	43	19	44.15	79	12	57.51	691122	93.9	C	0.0	0.0

STN CELL U.T.M. LATITUDE LONGITUDE DATE DEPTH SK-KU MODES
NO. SIZE NORTHING EASTING D M S D M S YYMMDD METRE SECTOR 1 2

STN NO.	CELL SIZE	U.T.M. NORTHING	U.T.M. EASTING	LATITUDE D	M	S	LONGITUDE D	M	S	DATE YYMMDD	DEPTH METRE	SK-KU SECTOR	MODES 1	MODES 2
71	A	4799372.	647614.	43	20	4.72	79	10	44.85	691121	91.9	C	0.0	0.0
72	A	4800292.	653579.	43	20	25.92	79	8	32.53	691104	86.6	C	0.0	0.0
73	A	4800865.	653440.	43	20	46.73	79	6	24.76	690702	87.2	C	0.0	0.0
74	A	4801448.	656521.	43	21	6.79	79	4	7.35	690702	88.6	C	0.0	0.0
75	B	4797915.	645983.	43	19	18.41	79	12	3.11	691122	89.9	C	0.0	0.0
76	B	4798127.	646826.	43	19	24.92	79	11	21.05	691124	88.9	C	0.0	0.0
77	B	4798617.	648860.	43	19	39.24	79	9	50.29	691121	85.9	C	0.0	0.0
78	B	4798832.	649795.	43	19	45.68	79	9	8.59	691114	83.8	C	0.0	0.0
79	B	4799328.	651839.	43	20	0.27	79	7	37.40	691031	79.8	C	0.0	0.0
80	B	4799548.	652776.	43	20	6.71	79	6	55.57	691030	74.8	B	0.0	0.0
81	B	4800025.	654795.	43	20	20.67	79	5	25.48	690702	77.7	C	0.0	0.0
82	B	4800243.	655750.	43	20	27.02	79	4	42.87	690702	78.3	B	0.0	0.0
83	C	4797651.	646275.	43	19	10.19	79	11	45.93	691124	87.9	C	0.0	0.0
84	C	4797734.	646575.	43	19	12.38	79	11	32.55	691124	87.9	C	0.0	0.0
85	C	4798374.	649255.	43	19	31.23	79	9	33.00	691121	81.9	C	0.0	0.0
86	C	4798442.	649555.	43	19	33.19	79	9	19.66	691114	81.8	B	0.0	0.0
87	C	4799098.	652233.	43	19	52.51	79	7	20.12	691030	72.8	B	0.0	0.0
88	C	4799165.	652530.	43	19	54.52	79	7	6.87	691030	71.8	C	0.0	0.0
89	C	4799768.	655182.	43	20	12.04	79	5	8.56	690626	74.5	B	0.0	0.0
90	C	4799840.	655493.	43	20	14.16	79	4	54.69	690626	74.2	C	0.0	0.0
91	D	4797586.	646410.	43	19	7.68	79	11	40.31	691124	87.9	C	0.0	0.0
92	D	4797619.	646502.	43	19	8.38	79	11	35.92	691124	86.9	C	0.0	0.0
93	D	4798290.	649387.	43	19	28.41	79	9	27.20	691121	80.9	C	0.0	0.0
94	D	4798316.	649474.	43	19	29.18	79	9	23.34	691114	80.8	C	0.0	0.0
95	D	4799110.	652360.	43	19	49.57	79	7	14.58	691031	71.8	C	0.0	0.0
96	D	4799123.	652447.	43	19	49.93	79	7	10.68	691031	70.8	B	0.0	0.0
97	D	4799732.	655329.	43	20	9.80	79	5	2.10	690702	72.9	C	0.0	0.0
98	D	4799763.	655420.	43	20	9.78	79	4	58.05	691030	73.4	C	0.0	0.0
99	E	4797565.	646449.	43	19	6.95	79	11	38.30	691124	87.9	C	0.0	0.0
100	E	4797576.	646482.	43	19	7.25	79	11	36.84	691124	86.9	C	0.0	0.0
101	E	4798271.	649424.	43	19	27.76	79	9	25.77	691121	79.9	C	0.0	0.0
102	E	4798277.	649457.	43	19	27.93	79	9	24.12	691114	80.8	C	0.0	0.0
103	E	4798934.	652364.	43	19	48.73	79	7	13.52	691031	70.8	C	0.0	0.0
104	E	4798924.	652420.	43	19	48.69	79	7	11.95	691031	70.8	B	0.0	0.0
105	E	4799670.	655361.	43	20	8.75	79	5	0.72	690702	72.7	C	0.0	0.0
106	E	4799687.	655399.	43	20	9.27	79	4	59.00	690702	72.7	C	0.0	0.0
107	F	4797522.	646452.	43	19	5.69	79	11	35.22	691124	86.9	C	0.0	0.0
108	F	4797520.	646490.	43	19	5.78	79	11	36.53	691124	86.9	C	0.0	0.0
109	F	4798139.	649434.	43	19	26.72	79	9	25.21	691121	79.9	C	0.0	0.0
110	F	4798245.	649465.	43	19	26.89	79	9	23.82	691114	79.8	C	0.0	0.0
111	F	4798957.	652397.	43	19	47.84	79	7	12.38	691031	69.6	C	0.0	0.0
112	F	4798967.	652429.	43	19	48.13	79	7	11.56	691031	69.8	B	0.0	0.0
113	F	4799639.	655359.	43	20	7.74	79	5	0.82	690702	72.6	C	0.0	0.0
114	F	4799658.	655396.	43	20	8.02	79	4	59.34	690702	72.5	C	0.0	0.0
115	D	4797492.	646433.	43	19	4.64	79	11	35.16	691124	86.9	C	0.0	0.0
116	D	4797550.	646525.	43	19	5.13	79	11	34.36	691124	85.9	C	0.0	0.0
117	D	4798196.	649414.	43	19	25.34	79	9	26.57	691121	79.9	C	0.0	0.0
118	D	4798227.	649552.	43	19	26.27	79	9	22.19	691114	77.8	C	0.0	0.0
119	D	4798916.	652384.	43	19	46.52	79	7	13.76	691031	69.6	B	0.0	0.0
120	D	4798944.	652475.	43	19	47.36	79	7	9.53	691031	69.6	C	0.0	0.0
121	D	4799597.	655333.	43	20	6.26	79	5	2.33	690626	72.8	B	0.0	0.0
122	D	4799616.	655425.	43	20	7.01	79	4	57.94	690626	72.8	C	0.0	0.0
123	C	4797367.	646350.	43	19	0.65	79	11	42.87	691124	86.9	C	0.0	0.0
124	C	4797437.	646649.	43	19	2.57	79	11	29.56	691124	85.9	C	0.0	0.0
125	C	4798074.	649726.	43	19	21.44	79	9	13.16	691121	79.9	C	0.0	0.0
126	C	4798157.	649675.	43	19	23.77	79	9	15.33	691114	77.8	C	0.0	0.0
127	C	4798732.	652307.	43	19	42.24	79	7	17.13	691031	67.8	B	0.0	0.0
128	C	4798853.	652608.	43	19	44.30	79	7	3.72	691031	67.8	C	0.0	0.0
129	C	4799469.	655260.	43	20	2.30	79	5	5.38	690626	72.[illegible]	C	0.0	0.0
130	C	4799536.	655559.	43	20	4.33	79	4	52.07	690626	72.[illegible]	B	0.0	0.0
131	B	4796375.	646113.	43	18	45.11	79	11	53.77	691122	84.9	C	0.0	0.0
132	B	4797182.	647040.	43	18	54.15	79	11	12.44	691124	82.9	C	0.0	0.0
133	B	4797677.	649085.	43	19	6.75	79	9	41.25	691121	76.9	C	0.0	0.0
134	B	4797896.	[illegible]	43	19	15.19	79	8	59.52	691114	71.8	C	0.0	0.0
135	B	4798394.	652053.	43	19	29.85	79	7	28.81	691031	67.8	B	0.0	0.0
136	B	4798612.	653004.	43	19	36.20	79	6	46.39	691031	62.8	B	0.0	0.0
137	B	4799193.	655016.	43	19	54.31	79	5	16.61	690626	66.8	C	0.0	0.0
138	B	[illegible]	655951.	43	19	56.32	79	4	34.92	690626	68.4	B	0.0	0.0
139	A	4795712.	645333.	43	18	7.73	79	12	29.58	691122	79.9	C	0.0	0.0
140	A	4796422.	648297.	43	18	28.64	79	10	17.42	691124	68.9	C	0.0	0.0
STN NO.	CELL SIZE	U.T.M. NORTHING	U.T.M. EASTING	LATITUDE D	M	S	LONGITUDE D	M	S	DATE YYMMDD	DEPTH METRE	SK-KU SECTOR	MODES 1	MODES 2

STN NO.	CELL SIZE	U.T.M. NORTHING	U.T.M. EASTING	LATITUDE D	LATITUDE M	LATITUDE S	LONGITUDE D	LONGITUDE M	LONGITUDE S	DATE YYMMDD	DEPTH METRE	SK-KU SECTOR	MODES 1	MODES 2
141	A	4797132.	651271.	43	18	49.53	79	8	4.77	691106	32.8	C	3.5	0.0
142	A	4797826.	654260.	43	19	9.83	79	5	51.47	690617	12.3	E	1.9	0.0
143	A	4798532.	657218.	43	19	30.49	79	3	39.45	690617	18.5	A	2.5	0.0
144	B	4794954.	646580.	43	17	41.38	79	11	34.39	691122	56.9	B	3.5	0.0
145	B	4795174.	647501.	43	17	46.78	79	10	53.94	691128	45.9	G	3.4	0.0
146	B	4795650.	649552.	43	18	2.75	79	9	22.50	691102	20.8	B	3.6	3.1
147	B	4795869.	650490.	43	18	9.16	79	8	40.65	691102	19.8	B	3.1	0.0
148	B	4796356.	652515.	43	18	23.49	79	7	10.37	690622	14.7	A	1.9	0.0
149	B	4796578.	653470.	43	18	29.97	79	6	27.74	690622	15.1	A	2.1	0.0
150	B	4797066.	655502.	43	18	44.28	79	4	57.10	690617	13.7	A	2.4	0.0
151	B	4797297.	656514.	43	18	51.01	79	4	11.98	690617	13.8	A	1.9	0.0
152	C	47947[illegible].	646966.	43	17	33.79	79	11	18.12	691206	40.9	B	3.6	0.0
153	C	4794771.	647273.	43	17	35.89	79	11	4.42	691128	38.9	C	3.4	0.0
154	C	4795412.	649944.	43	17	54.74	79	9	5.35	691128	18.9	F	3.1	3.6
155	C	4795486.	650247.	43	17	56.92	79	8	51.81	691125	18.9	F	3.1	2.6
156	C	4796[illegible].	652921.	43	18	15.23	79	6	52.60	690622	14.4	A	2.1	0.0
157	C	4796176.	653224.	43	18	17.14	79	6	39.35	690622	14.1	A	2.1	0.0
158	C	4796817.	655898.	43	18	35.92	79	4	39.79	690618	13.1	A	2.6	0.0
159	C	4796888.	656196.	43	18	37.95	79	4	26.50	690618	13.5	A	2.5	1.9
160	D	4794619.	647108.	43	17	31.08	79	11	11.91	691206	37.9	G	3.5	0.0
161	D	4794637.	647191.	43	17	31.58	79	11	8.19	691128	36.9	F	3.5	0.0
162	D	4795331.	650[illegible]78.	43	17	52.03	79	8	59.47	691128	18.9	E	3.1	3.6
163	D	4795353.	650166.	43	17	52.69	79	8	55.47	691125	18.9	E	3.1	3.6
164	D	4796029.	653048.	43	18	12.48	79	6	47.02	690622	14.1	A	2.1	0.0
165	D	4796053.	653139.	43	18	13.21	79	6	42.95	690622	13.9	A	2.1	0.0
166	D	4796736.	656021.	43	18	33.20	79	4	34.42	690618	11.6	A	2.6	0.0
167	D	4796758.	656109.	43	18	33.83	79	4	30.49	690618	11.6	A	2.6	0.0
168	E	4794566.	647137.	43	17	30.31	79	11	10.65	691206	36.9	B	3.6	0.0
169	E	4794616.	647170.	43	17	30.92	79	11	9.14	691128	36.9	B	3.6	0.0
170	E	4795318.	650110.	43	17	51.58	79	8	58.36	691128	18.9	B	3.1	3.6
171	E	4795324.	650145.	43	17	51.74	79	8	56.51	691127	18.9	E	3.1	0.0
172	E	4796[illegible].	653088.	43	18	12.17	79	6	45.26	690623	14.[illegible]	A	2.1	0.0
173	E	4796026.	653112.	43	18	12.34	79	6	44.2[illegible]	690622	13.9	A	2.[illegible]	0.0
174	E	4796718.	656056.	43	18	32.28	79	4	32.88	690621	10.2	A	2.6	0.0
175	E	4796724.	656097.	43	18	32.75	79	4	31.05	690621	10.1	A	2.5	0.0
176	E	4794567.	647143.	43	17	29.35	79	11	10.41	691206	35.9	B	3.5	0.0
177	E	4794574.	647174.	43	17	29.56	79	11	9.03	691128	35.9	B	3.5	0.0
178	E	4795277.	650119.	43	17	50.26	79	8	57.7[illegible]	691129	18.9	B	3.1	3.6
179	E	4795279.	650156.	43	17	50.29	79	8	56.35	691127	18.9	E	3.1	3.6
180	E	4795985.	653092.	43	18	11.33	79	6	45.11	690623	13.9	A	2.1	0.0
181	E	4795996.	653116.	43	18	11.36	79	6	44.35	690623	14.[illegible]	A	2.4	0.0
182	E	4796584.	656067.	43	18	31.49	79	4	32.45	690621	9.2	A	2.4	0.0
183	E	4796693.	656101.	43	18	31.75	79	4	30.94	690621	9.5	A	2.6	0.0
184	D	4794532.	647121.	43	17	28.24	79	11	11.43	691206	35.9	B	3.5	0.0
185	D	4794549.	647210.	43	17	28.73	79	11	7.43	691206	35.9	F	3.5	0.0
186	D	4795247.	650[illegible]95.	43	17	49.30	79	8	58.79	691128	18.9	F	3.1	0.0
187	D	4795259.	650185.	43	17	49.51	79	8	54.79	691127	18.9	F	2.9	3.6
188	D	4795951.	653070.	43	18	9.94	79	6	46.14	690623	13.6	A	2.1	0.0
189	D	4795968.	653161.	43	15	10.43	79	6	42.38	690623	13.8	A	2.1	0.0
190	D	4796645.	656034.	43	18	30.25	79	4	33.96	690621	8.5	A	2.1	0.0
191	D	4796677.	656132.	43	18	31.09	79	4	29.56	690621	9.4	A	2.5	0.0
192	C	4794395.	647041.	43	17	23.86	79	11	15.09	691206	34.9	B	3.[illegible]	0.0
193	C	4794466.	647343.	43	17	26.30	79	11	1.64	691206	31.9	B	3.6	0.0
194	C	4795117.	650009.	43	17	45.02	79	9	2.72	691128	18.9	E	3.1	1.9
195	C	4795181.	650320.	43	17	47.01	79	8	48.96	691125	17.9	E	3.1	1.9
196	C	4795814.	652985.	43	18	5.57	79	6	49.84	690623	13.7	A	2.1	0.0
197	C	4795892.	653291.	43	18	7.87	79	6	36.37	690623	14.0	A	2.4	0.0
198	C	4796526.	655962.	43	18	26.43	79	4	37.26	690618	10.6	A	2.1	0.0
199	C	4796592.	656259.	43	18	28.36	79	4	23.99	690618	9.6	A	2.5	0.0
200	B	4794105.	646807.	43	17	11.38	79	11	25.64	691122	39.9	F	3.5	3.1
201	B	4794227.	647738.	43	17	17.94	79	10	44.35	691206	22.9	F	3.5	0.0
202	B	4794715.	649770.	43	17	32.28	79	9	13.72	691102	17.8	E	3.1	3.6
203	B	4794934.	650711.	43	17	38.71	79	8	31.80	691102	15.8	E	1.9	0.0
204	B	4795419.	652740.	43	17	52.96	79	7	1.28	690621	13.1	A	2.1	0.0
205	B	4795645.	653685.	43	17	59.61	79	6	19.17	690621	10.5	E	2.6	0.0
206	B	4796118.	655709.	43	18	13.41	79	4	48.86	690618	5.9	E	1.9	0.0
207	B	4796348.	656663.	43	18	20.14	79	4	6.35	690617	10.3	E	2.4	0.0
208	B	4793742.	646[illegible].	43	16	31.33	79	12	[illegible].81	691122	22.9	F	3.5	2.1
209	A	4793454.	648995.	43	16	51.53	79	9	49.18	691122	17.3	E	3.1	0.0
210	A	4794167.	651959.	43	17	12.95	79	7	37.13	690623	14.9	A	1.9	0.0

STN CELL U.T.M. LATITUDE LONGITUDE DATE DEPTH SK-KU MODES
NO. SIZE NORTHING EASTING D M S D M S YYMMDD METRE SECTOR 1 2

STN NO.	CELL SIZE	U.T.M. NORTHING	U.T.M. EASTING	LATITUDE D	LATITUDE M	LATITUDE S	LONGITUDE D	LONGITUDE M	LONGITUDE S	DATE YYMMDD	DEPTH METRE	SK-KU SECTOR	MODES 1	MODES 2
211	A	4794689.	654927.	43	17	34.19	79	5	24.82	690621	7.6	A	2.1	0.0
212	A	4795565.	657908.	43	17	57.85	79	3	11.91	690616	10.1	A	2.1	0.0
213	B	4791073.	647279.	43	16	5.21	79	11	6.56	691122	17.9	B	3.6	2.6
214	B	4792[illegible].	648214.	43	16	11.92	79	10	25.18	691122	16.9	B	3.6	0.0
215	B	4792666.	650256.	43	16	25.54	79	8	54.10	690627	14.2	A	3.1	2.1
216	B	4792835.	651181.	43	16	32.32	79	8	12.34	690627	12.5	A	2.5	0.0
217	B	4793390.	653219.	43	16	46.85	79	6	42.08	691102	5.6	A	2.6	0.0
218	B	4793511.	654168.	43	16	53.34	79	5	59.80	691102	6.8	A	2.5	[illegible]
219	B	4794[illegible]37.	656196.	43	17	7.58	79	4	29.36	691101	7.5	E	-0.6	1.5
220	B	4794310.	657145.	43	17	13.76	79	3	47.06	691101	10.8	A	2.1	0.0
221	C	4791743.	647655.	43	15	57.51	79	10	50.41	691208	16.9	B	3.6	0.0
222	C	47918[illegible]7.	647362.	43	15	59.37	79	10	36.74	6912[illegible]8	16.9	B	3.5	3.1
223	C	4792445.	650643.	43	16	17.95	79	8	37.25	690627	12.9	B	2.3	0.0
224	C	4792510.	650946.	43	16	20.00	79	8	23.76	690627	12.[illegible]	A	2.6	0.0
225	C	4793[illegible]49.	653614.	43	16	38.79	79	6	24.93	691102	4.2	A	2.1	0.0
226	C	47933[illegible]0.	653931.	43	16	40.18	79	6	1[illegible].71	691102	4.8	A	2.4	0.0
227	C	4793855.	656596.	43	16	59.43	79	4	11.85	691101	7.8	F	-1.1	1.6
228	C	4793920.	656898.	43	17	1.32	79	3	58.43	691101	9.8	E	2.1	0.0
229	D	4791638.	647784.	43	15	54.01	79	10	44.78	691206	16.9	B	3.6	0.0
230	D	4791670.	647870.	43	15	55.25	79	10	4[illegible].55	6912[illegible]8	16.9	B	3.6	[illegible]
231	D	4792372.	650773.	43	16	15.66	79	8	31.57	690628	12.[illegible]	A	2.6	0.0
232	D	4792389.	650856.	43	16	16.16	79	8	27.88	690628	12.2	A	2.6	0.0
233	D	4793076.	653741.	43	16	36.31	79	6	19.25	690705	6.[illegible]	E	1.3	2.6
234	D	4793[illegible]3.	653831.	43	16	37.11	79	6	15.25	690705	5.8	A	2.4	0.0
235	D	4793776.	656725.	43	16	56.78	79	4	6.21	691101	10.8	E	1.3	0.0
236	D	4793796.	656905.	43	16	57.37	79	4	2.68	691102	9.8	E	1.9	0.0
237	D	4791639.	647831.	43	15	53.99	79	10	42.70	691208	16.9	B	3.6	3.1
238	D	47916[illegible].	647962.	43	15	54.26	79	10	41.33	6912[illegible]	16.9	B	3.6	0.0
239	D	4792346.	650803.	43	16	14.76	79	8	3[illegible].28	6907[illegible]3	12.2	B	2.6	0.0
240	D	4792355.	650835.	43	16	15.08	79	8	28.84	6907[illegible]3	12.0	A	2.5	0.0
241	D	4793055.	653777.	43	16	35.59	79	6	17.70	690705	6.8	A	3.1	2.6
242	D	4793[illegible]64.	653906.	43	16	35.88	79	6	16.40	6907[illegible]	5.8	A	1.9	0.0
243	D	4793748.	656767.	43	16	55.83	79	4	4.47	6911[illegible]1	9.8	E	1.3	[illegible]
244	D	479375[illegible].	656790.	43	16	55.89	79	4	3.37	6911[illegible]2	9.8	F	1.5	-0.4
245	D	47916[illegible]1.	647833.	43	15	5[illegible].78	79	10	42.04	6912[illegible]9	15.9	D	3.5	0.0
246	D	4791612.	647870.	43	15	5[illegible].09	79	10	41.63	6912[illegible]5	15.9	B	3.4	0.0
247	D	47923[illegible].	6508[illegible].	43	16	[illegible]	79	8	29.36	6907[illegible]	12.[illegible]	B	2.6	[illegible]
248	D	4792337.	65[illegible]843.	43	16	14.34	79	8	28.49	6907[illegible]3	12.[illegible]	A	2.6	0.0
249	D	4793[illegible]27.	65379[illegible].	43	16	34.68	79	6	17.12	690705	6.[illegible]	A	2.4	0.0
250	D	4793[illegible]32.	6538[illegible].	43	16	34.82	79	6	15.30	6907[illegible]5	5.6	A	1.5	2.4
251	D	4793726.	65677[illegible].	43	16	55.13	79	4	4.27	6911[illegible]	9.3	F	-[illegible].4	[illegible]
252	D	4793728.	656797.	43	16	55.17	79	4	3.19	691102	9.8	F	1.6	[illegible].1
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256	D	47922[illegible]9.	650677.	43	16	13.[illegible]	79	8	27.33	690628	12.[illegible]	A	2.6	0.0
257	D	4792988.	653763.	43	16	33.45	79	6	18.37	6907[illegible]5	6.1	A	2.5	0.0
258	D	4793[illegible].	653845.	43	16	33.31	79	6	14.68	691209	5.[illegible]	A	2.4	1.9
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260	D	4793695.	656823.	43	16	54.07	79	4	1.98	691102	9.8	E	1.6	1.1
261	C	479[illegible]446.	647734.	43	15	47.81	79	10	47.20	691208	15.9	G	0.7	0.0
262	C	4791516.	648[illegible]30.	43	15	49.83	79	10	34.02	691206	15.9	B	3.6	0.0
263	C	479[illegible]46.	650707.	43	16	8.49	79	8	34.70	690628	12.0	A	2.5	[illegible].0
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265	C	4792855.	653673.	43	16	29.54	79	6	22.5[illegible]	6907[illegible]5	6.[illegible]	E	2.1	0.0
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269	B	479[illegible].	647493.	43	15	34.41	79	10	58.29	6912[illegible]9	14.9	B	[illegible]	0.0
270	B	4791274.	648427.	43	15	41.66	79	10	15.56	6912[illegible]5	17.[illegible]	C	3.6	0.0
271	B	479175[illegible].	650466.	43	15	55.79	79	8	45.7[illegible]	690625	1[illegible]	B	3.1	3.5
272	B	479[illegible]576.	651403.	43	16	2.38	79	8	4.91	690628	8.7	A	[illegible]	0.0
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274	B	4792759.	654338.	43	16	25.61	79	5	53.10	690705	8.2	A	2.5	0.0
275	B	4793168.	656421.	43	16	37.32	79	4	2[illegible].33	69110[illegible]	7.6	E	1.3	0.0
276	B	4793376.	657362.	43	16	43.35	79	3	38.42	691101	6.8	A	2.1	0.0
277	B	4789766.	646705.	43	14	54.17	79	11	34.44	691209	9.9	B	[illegible]	0.0
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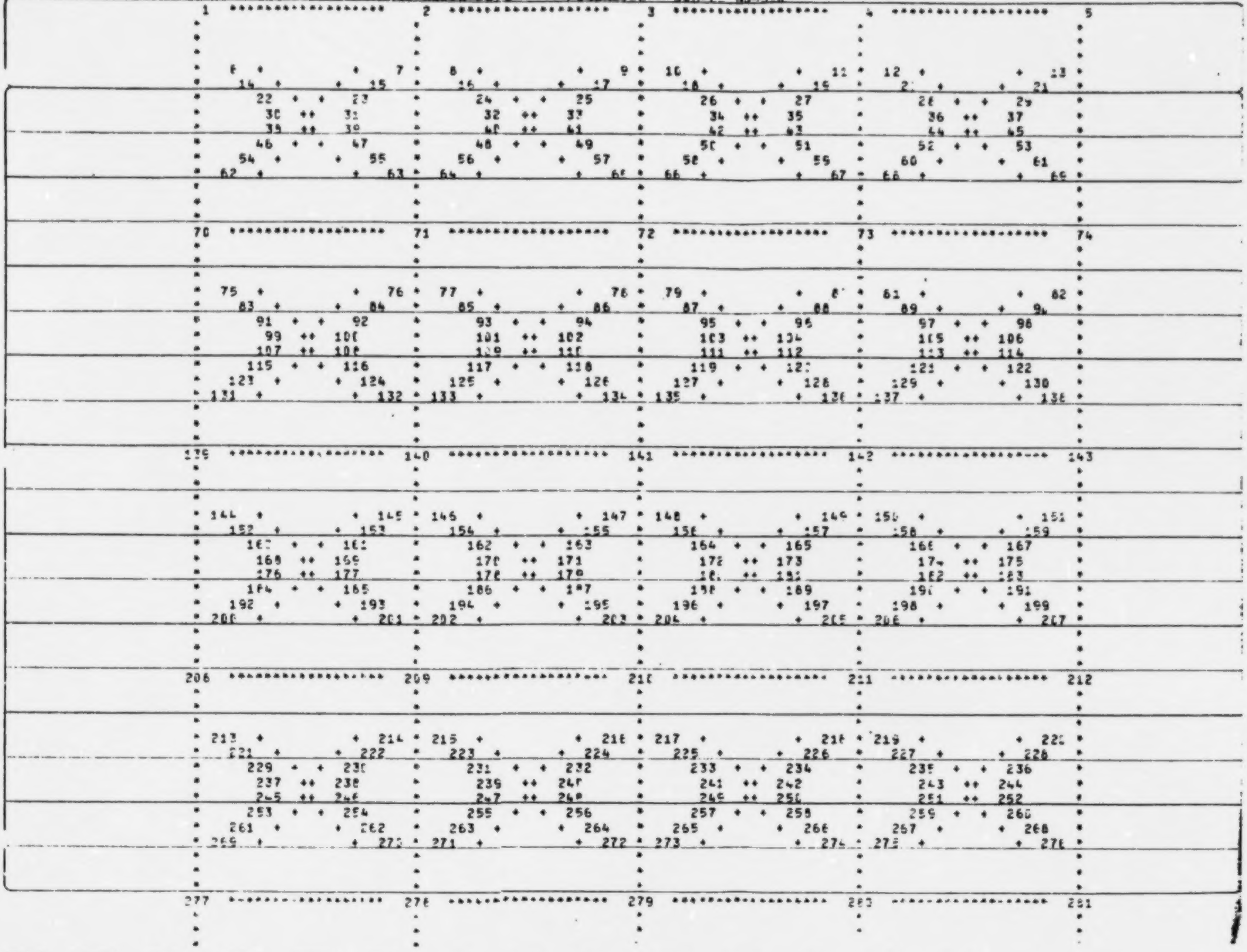
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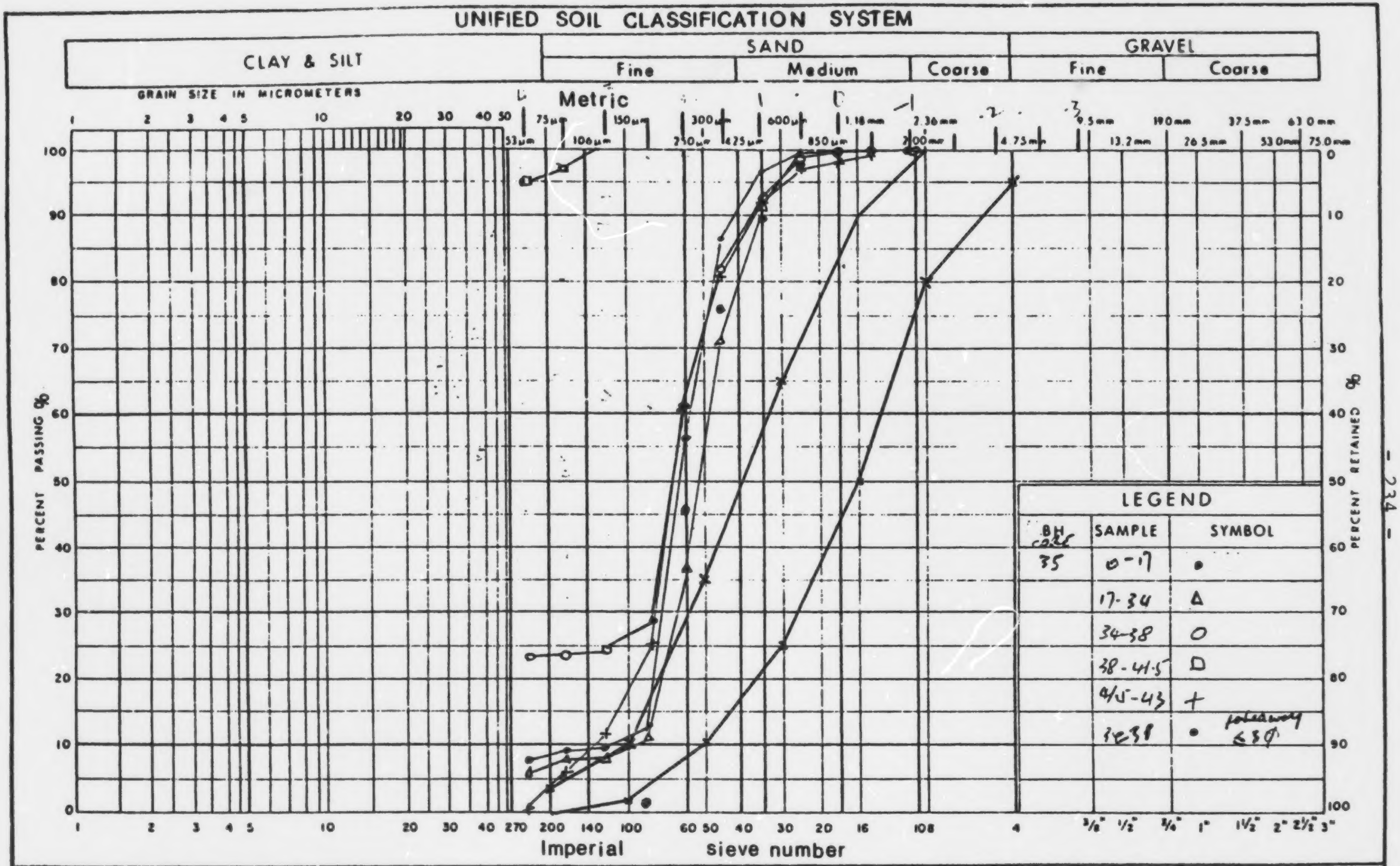
APPENDIX VI

DIAGRAM OF SELECTED GRAIN SIZE DISTRIBUTION



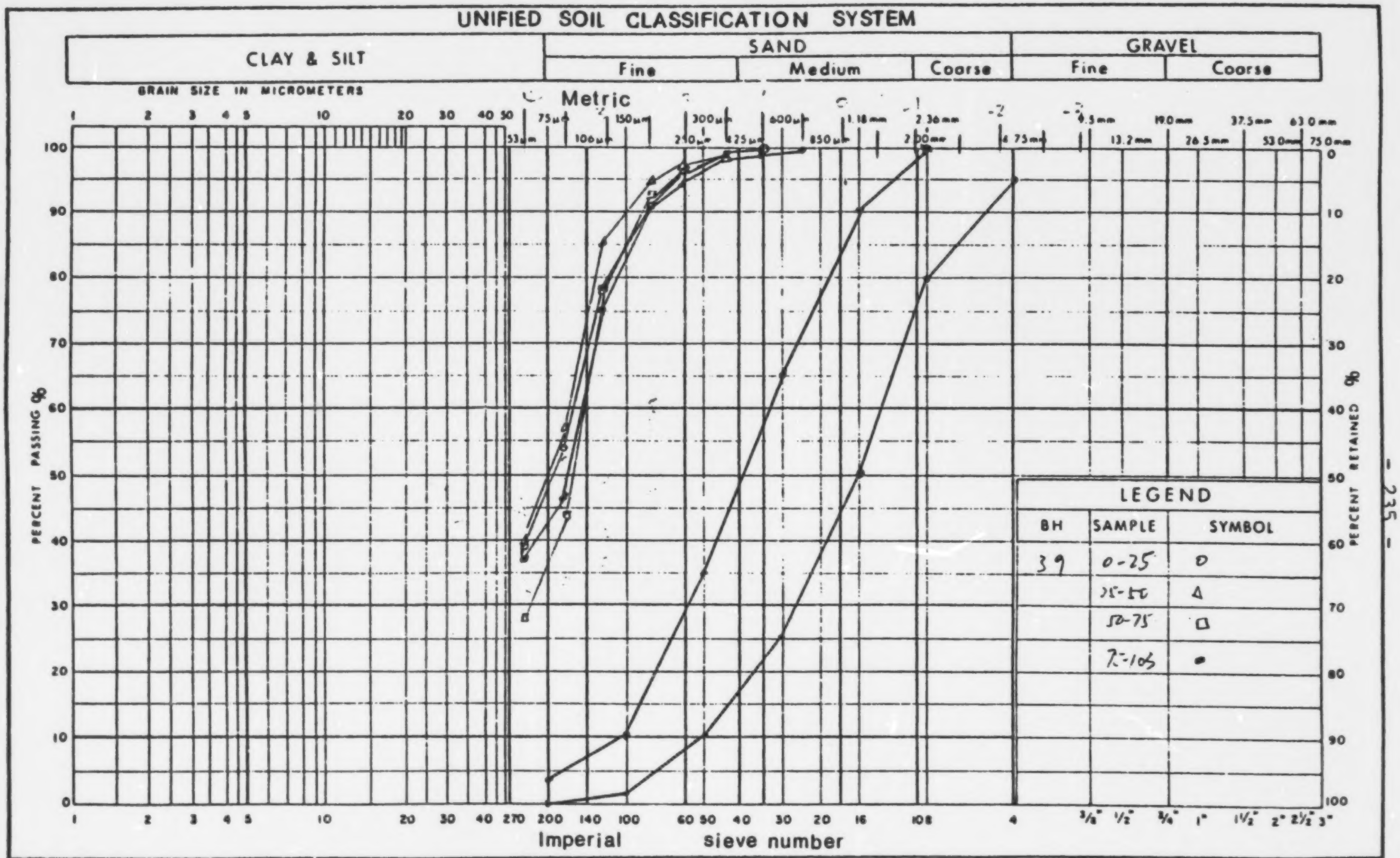
GRAIN SIZE DISTRIBUTION

CORE -35 (Data from Rukavina)

Niagara Bar, Lake Ontario

FIG NO	
PROJECT	
SITE	

WHOLE SAMPLE

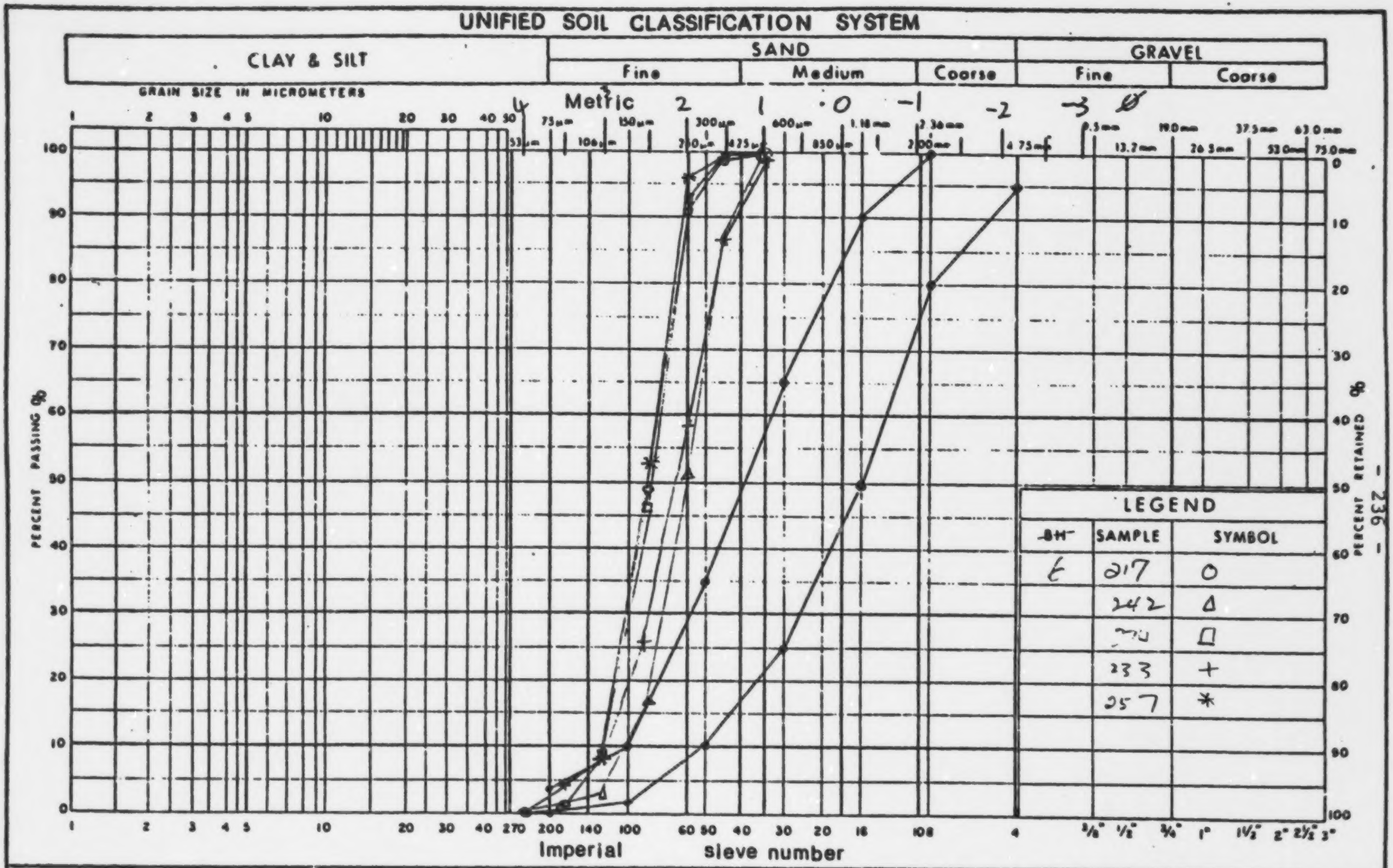


GRAIN SIZE DISTRIBUTION

CORE 39, West of Viggins Fetr

(Data from Rukavina)

FIG NO	
PROJECT	
SITE	

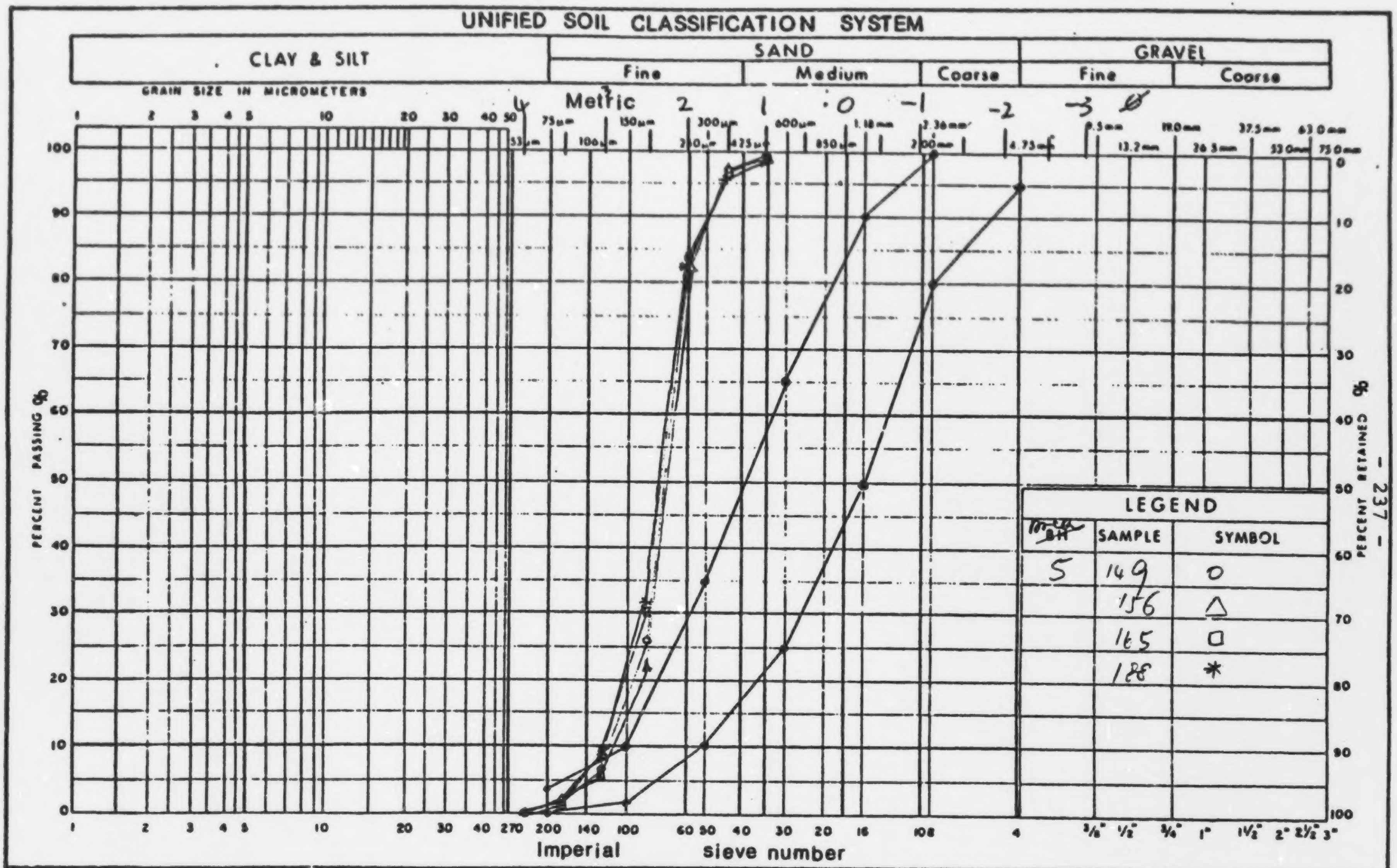


GRAIN SIZE DISTRIBUTION

Inner Bar, Canadian Side

(Data from Sly)

FIG NO	
PROJECT	
SITE	

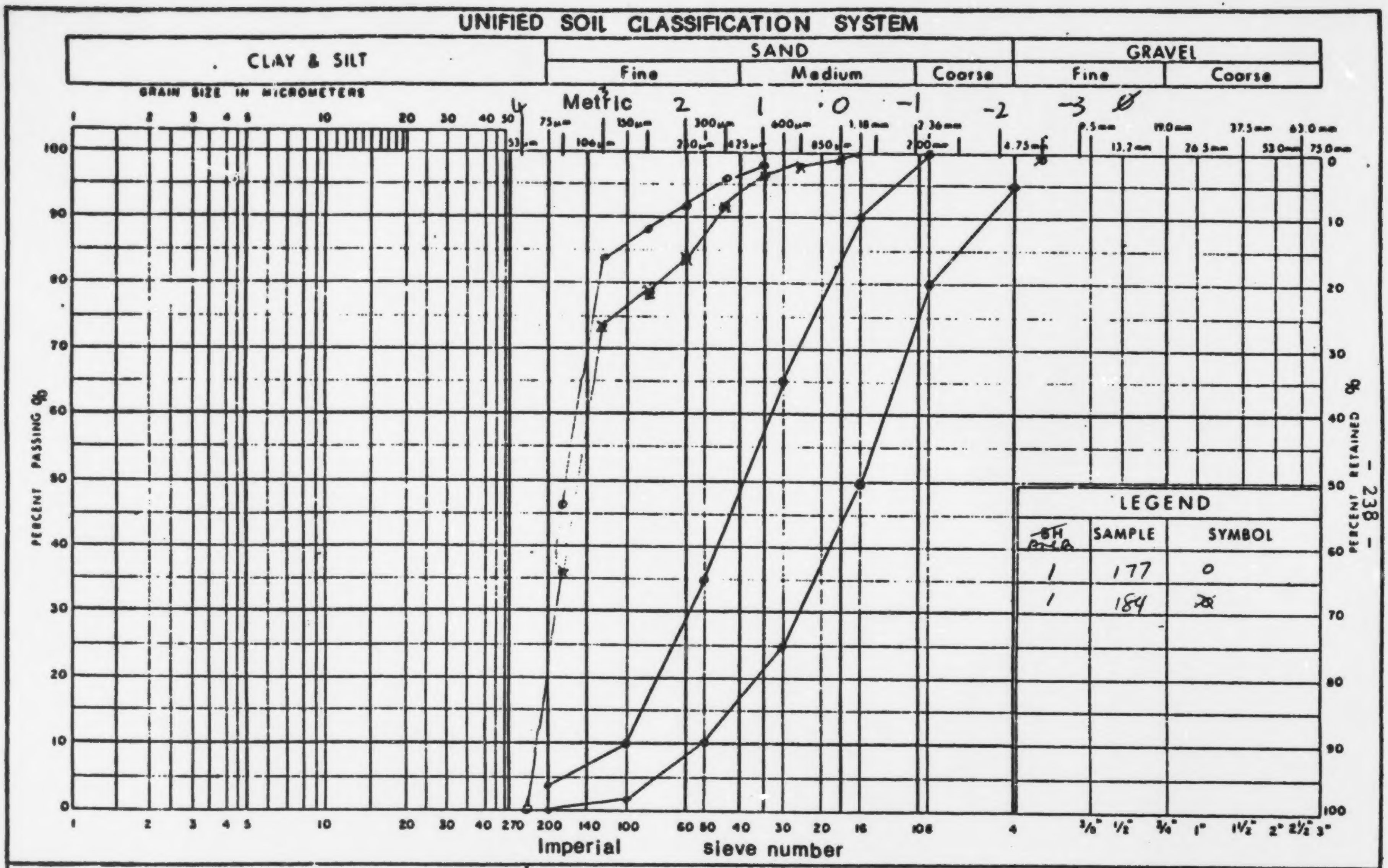


GRAIN SIZE DISTRIBUTION

Area between Outer + Inner Bar

(Data from Sly)

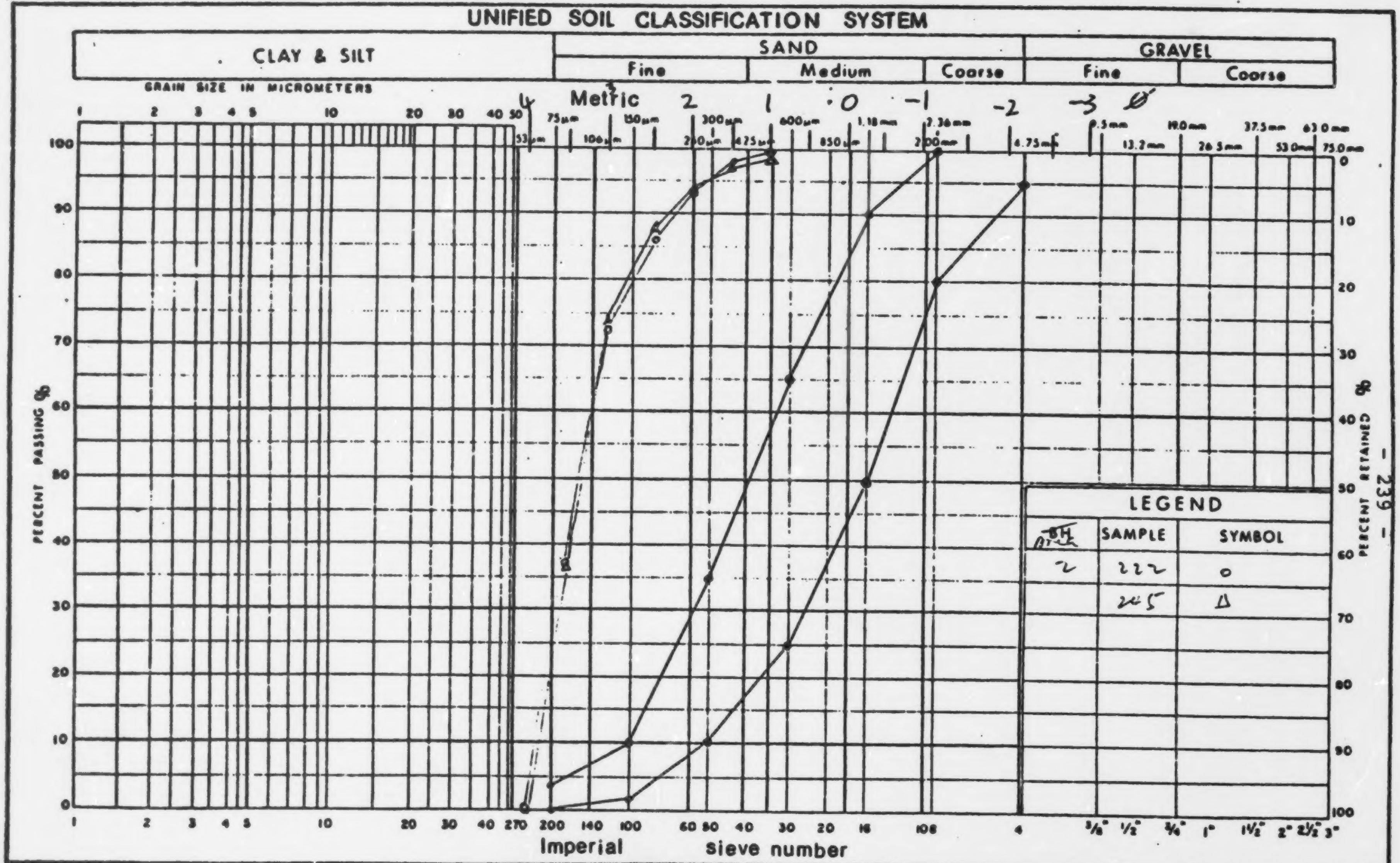
FIG NO	
PROJECT	
SITE	



GRAIN SIZE DISTRIBUTION

Ice-Rafted sediment NW of
Niagara Park
(Data from [illegible])

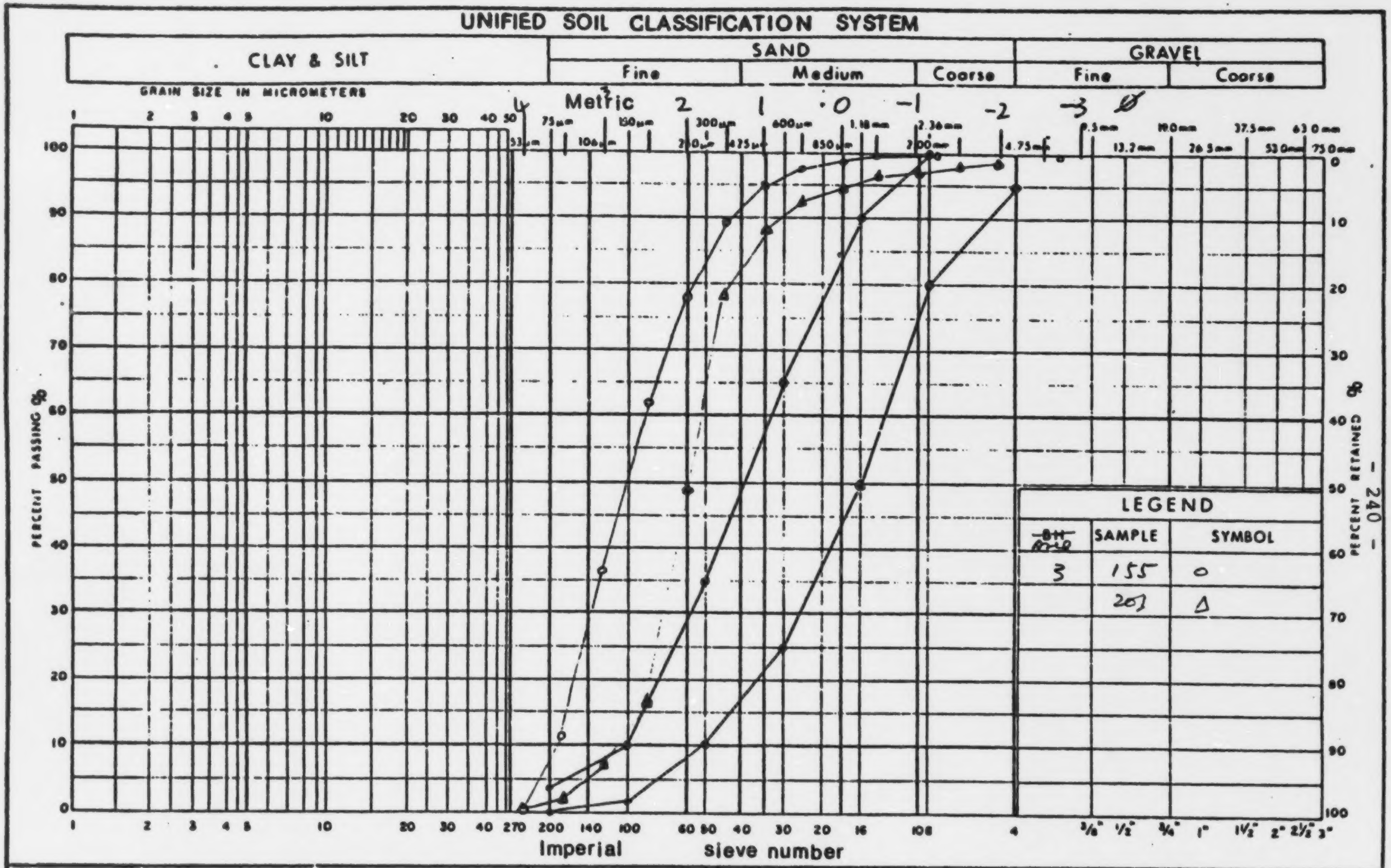
FIG NO	
PROJECT	
SITE	



GRAIN SIZE DISTRIBUTION

Area off Six Mile Creek,
Lake Ontario.
(Data from Shg)

FIG NO	
PROJECT	
SITE	



GRAIN SIZE DISTRIBUTION

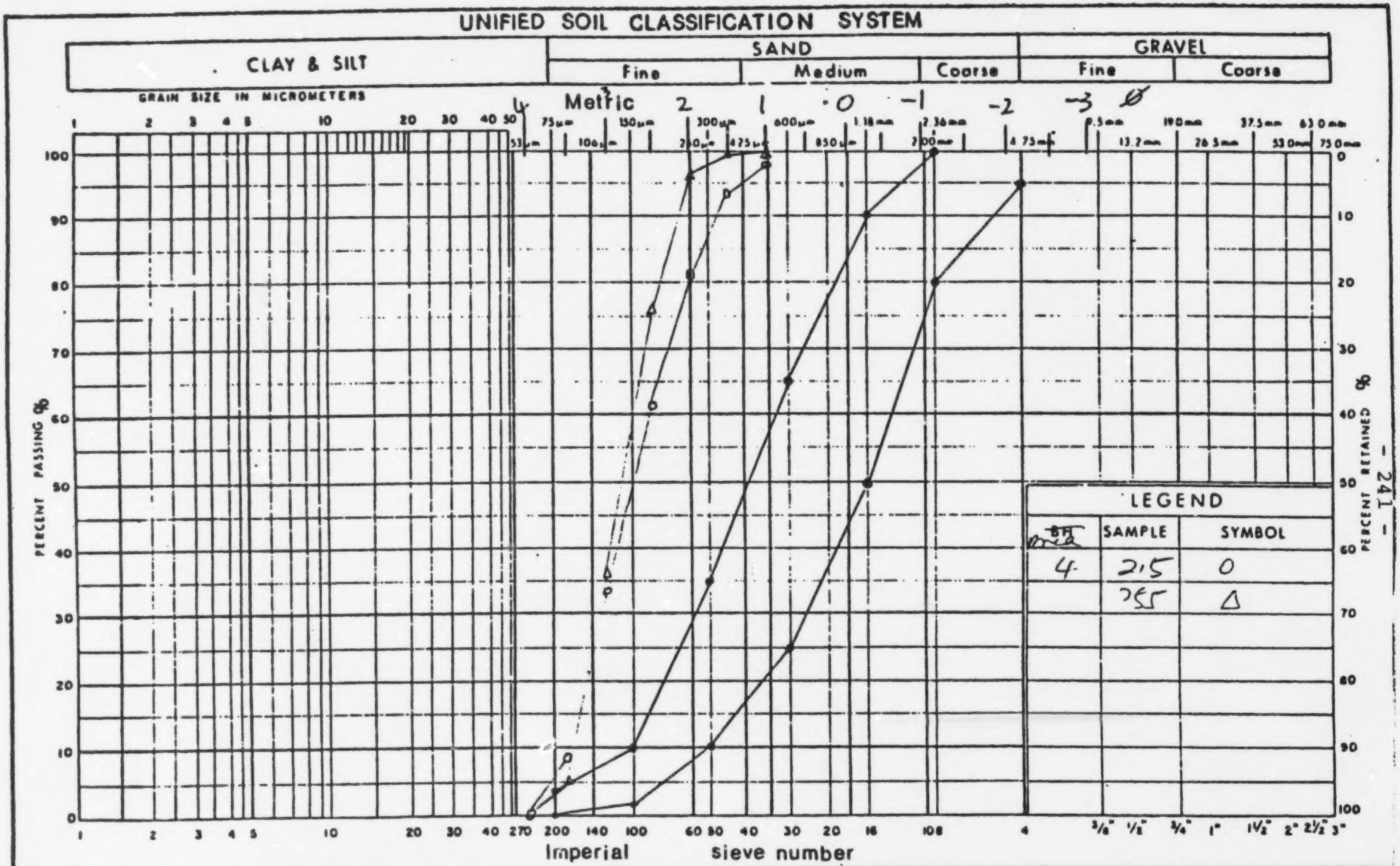
Area immediately off [illegible] Outer Bar

(Data from Sly)

FIG NO

PROJECT

SITE



GRAIN SIZE DISTRIBUTION

Area off Four Mile Point
(Data from Sly)

FIG NO	
PROJECT	
SITE	

APPENDIX VII

GEOLOGY AND ENGINEERING PROPERTIES OF STONE IN NIAGARA

APPENDIX VII

GEOLOGY AND ENGINEERING PROPERTIES OF STONE IN NIAGARA

Introduction

The various near-surface formations within the Niagara Region are described in this Appendix. Detailed descriptions of the rock types present, their vertical and lateral extent as well as an assessment of their suitability for various aggregate products is included in the following subsections.

Queenston Formation

Outcropping at the base of the Niagara Escarpment and stretching east-west across the northern fringe of the Region is the Queenston formation. This material consists of a red, hematitic fissile and micaceous calcareous shale (ODM, 1976) which represents the uppermost strata of Ordovician age exposed in the area. Although the shale cannot be used for aggregates, it has good ceramic properties and Canada Brick in the Town of Niagara-on-the-Lake is currently using the material for the manufacture of bricks and tiles.

CATARACT GROUP

Overlying the red Queenston shale is the Cataract Group of the Alexandrian Series. This consists of the Whirlpool Sandstone, the Cabot Head shales and the red shales and sandstones of the Grimsby Formation.

Whirlpool Formation

The Whirlpool Formation consists of a medium to thick-bedded, brown weathered, light tan to grey quartz sandstone. It is fine to very fine-grained and the grains are subrounded and well-sorted. Thin shale partings and seams can occur (ODM, 1976). At its reference section at The Whirlpool in the Niagara Gorge, the unit is about 7.5 m thick. The Whirlpool Sandstone is currently being quarried for Building stone in some parts of Ontario.

The Whirlpool is a beautiful durable stone which has often been referred to as Credit Valley Sandstone. "the potential for future mining of this stone in the Niagara Region has not been assessed but such a study may be warranted for it appears that the potential is there" (Caley, 1940).

It has been suggested that the Whirlpool Formation could also provide a suitable aggregate in view of the fact that it is a very clean sandstone and its grains are cemented by silica. Although no testing has been done thus far, it is felt that Whirlpool sandstone would have a high potential for alkali-silica reactivity (Rogers, personal communication) and reserves would be too low for commercial extraction for aggregates.

Cabot Head Formation

The Cabot Head Formation is composed of a finely laminated grey and green shale with interbeds of sublithographic or finely crystalline limestone with occasional siltstone (ODM, 1976). Although the material is susceptible to weathering, the material is generally suitable for the production of brick, tile and expanded aggregate. There is no current production because exposures suitable for quarrying are scarce (Vos, 1969). At Decew Falls, this unit is approximately 14.5 m thick.

Grimsby Formation

The Grimsby Formation is composed of fine-grained sandstone with interbedded shale. Hematite causes the shale to take on a red colour on weathered surfaces but greens are also evident. At Decew Falls, the unit is about 13m thick but there is a gradual increase in thickness from east to west across the Region (ODM, 1976; Vos, 1969).

CLINTON GROUP

Overlying the Cataract Group is the Clinton Group of the Niagaran Series consisting of the Thorold Sandstone, the Neahga Shale, the Reynales Dolomite, the Irondequoit Limestone, the Rochester Shale and the Decew Limestone.

Thorold Formation

The Thorold Formation is a thin-bedded white to light grey or greenish, very fine-grained quartzose sandstone (almost a siltstone) containing very thin green shale partings. On weathered and wet surfaces, the colour is distinctly greenish.

This unit can be observed at several locations within the Region. The thickness of the unit varies from 2 to 3 m within the Niagara Region but can be up to 4m in other parts of the escarpment (ODM, 1976; Vos, 1969).

Neagha Formation

The Neagha Formation lies conformably on the Thorold Sandstone and consists of a green to olive-green shale containing some minor very finely crystalline blue limestone and phosphate pellets in some areas of the Niagara Gorge.

This unit can only be observed at a few places within the Region. It thins from 2 m at the Niagara Gorge to less than .5 m at Decew Falls. (ODM, 1976).

Reynales Formation

The Reynales Formation can be subdivided into two members. The lower member consists of thin to medium beds of blue, finely crystalline dolostones containing grey shale partings throughout. This member contains sulphides such as pyrite, marcasite and chalcopyrite as well as glauconite phosphate pellets and minor chert.

The upper member consists of predominantly lithographic and sublithographic, weakly laminated dolostone with occasional shale partings. A sandstone band or conglomerate can occur at the contact with the Irondequoit limestone in some areas.

This unit is well exposed along the Niagara Escarpment. The total thickness of the formation varies from 4 m (.8 m and 3.2 m for lower and upper members respectively) at the Sir Adam Beck Power Station to 3 m (.4 and 2.6 m for upper and lower members respectively) at Decew Falls (ODM, 1976; Vos, 1969).

The Reynales has been mined by Queenston Quarries.

Irondequoit Formation

The Irondequoit Formation consists of a medium to thick-bedded, light grey, fine to medium crystalline, porous limestone which can be partly dolomitic and highly fossiliferous (crinoidal). The lower contact with the Reynales Formation is sharp and the change from the lithographic texture of the upper Reynales to fine and medium crystalline textures of the Irondequoit are prominent at most localities.

This unit is well exposed in the Escarpment face in the same sections as the Reynales. The Irondequoit varies from 3 m at the Niagara Gorge to 4.4 m at Decew Falls.

Both the Irondequoit Limestone and the Reynales Dolomite have, in the past, been quarried for building stone (ODM, 1976; Vos, 1969). The Irondequoit has been quarried by Queenston Quarries.

Rochester Formation

The Rochester Formation consists of a black to dark grey, calcareous shale with numerous thin (50 mm) interbeds of lithographic and finely crystalline fossiliferous dolostone and limestone. The latter thicken and become more numerous towards Decew Falls. West of Grimsby, the formation becomes more compact.

This unit is moderately well exposed in the Escarpment face and can be seen at Decew Falls. The thickness of the Rochester shale is quite constant across the Niagara Region and averages approximately 17 m (ODM, 1976; Vos, 1969).

Decew Formation

The Decew Formation is well exposed across the escarpment and consists of massive to medium-bedded, dark grey, very finely crystalline, aphanitic and impure dolostone. A lower unit of 1.1 to 1.2 m thick of irregularly cross-bedded dolostone is often present. The upper part of the formation has a conchoidal fracture with a thin veneer of tan precipitate covering weathered faces.

The Decew Formation is well exposed along the Escarpment. The thickness of the Decew varies from 3.5 m at Niagara Gorge to 2.4 m at Decew Falls (ODM, 1976; Vos, 1969).

The Ministry of Transportation and Communications (MTC) have suggested that the Decew is a very clay-rich rock and may be considered unsuitable for many aggregate products. Tests on washed screenings and manufactured sand have shown that the Decew Dolomite can have very high Magnesium Sulphate Losses and breaks apart very easily. Therefore it is generally unsuitable for concrete (Rogers, personal communication). However, alkali-Reactivity tests by Ontario Hydro have shown that this material is essentially non-reactive with values ranging from 0.013 to 0.051 percent after 12 months.

It has been quarried between St. David's and Thorold as a source of natural cement (Vos, 1969) and rock wool. It is also being quarried by Walker Brothers Limited and Vineland Quarries (Hewitt, 1960).

The Cataract and Clinton Groups have been extracted in the past at various places in the province for use as building stone, crushed stone and cement but generally they are not well suited for aggregate production as well as being very limited in extent (OGS, in print). In addition, exposures of these formations are often in areas having significant recreational potential (OGS, in print).

ALBEMARLE GROUP

The crest of the Escarpment is formed by a thick sequence of erosion resistant dolomites belonging to the Albemarle Group of Middle Silurian age. The Albemarle Group which disconformably overlies the Clinton Group consists of the Lockport and Guelph Formations in the Niagara Region.

Lockport Formation

The Lockport Formation consists of a series of dolomites which can be divided into three members; the Gasport, Goat Island and Eramosa. Large amounts of good quality crushed stone are being produced from this formation and it is well-suited for load-bearing aggregate (OGS, in print) although the material tends to be rather soft and an objectionably high dust content may result.

The Lockport Formation shows average Los Angeles abrasion tests ranging from 13 to 25 percent loss, with occasional soft sections in the Gasport member of up to 39 percent loss. $MgSO_4$ soundess ranges from 2 to 13 percent loss, with some unsound shaly zones occaisionally reaching 22 percent loss. Absorption ranges from 0.4 to 1.6 percent (Hewitt, 1960). Absorption and coefficient of thermal expansion tests by this material gave average values of 1.13 percent and 4.8×10^6 / degree Fahrenheit respectively. Alkali-reactivity tests by Ontario Hydro have shown this material to be non-reactive (values ranging from 0.021 to 0.039 after 12 months)

Gasport Member

The Gasport Member is well-exposed along the rim of the Niagara Escarpment and can be seen at most major localities. It predominantly consists of massive to thick-bedded, fine to medium crystalline, grey (blue-grey on fresh surfaces), medium-bedded, porous and vuggy, crinoidal dolomitic limestone and dolostone.

The thickness of this member varies from 13.5m at Niagara Falls to 6.5 m at Decew Falls (ODM, 1976; Vos, 1969)

Alkali-Reactivity tests by Ontario Hydro on Gasport Limestone have shown this material to be essentially non-reactive (values ranged from 0.022 to 0.038 after 12 months). Absorption and coefficient of thermal expansion tests on this material by Ontario Hydro indicated average values of 1.24 percent and 5.2 X 10^{6} / Degree Fahrenheit respectively.

Massive basal beds of this member have been quarried for building stone at Queenston. This material is very durable, has low porosity and absorption and is readily sawn, machined and carved. It is also well-suited for the production of a range of aggregate products including concrete stone, hot-laid asphaltic stone and sand, granular base coarse, gabion stone and agricultural lime (OGS, in print). Aggregate is currently being produced at Walker Brothers and a substantial tonnage of pulverized stone, flux stone and pulp and paper mill stone used to be produced there. Queenston and Vineland Quarries also produce substantial quantities of road material (Vos, 1969) from this unit. It was also previously mined by St. Catherines Crushed Stone Limited and Beamsville Quarries.

Goat Island Member

Conformably overlying the Gasport Member is a massive to thick-bedded, light buff to light brownish grey, very fine crystalline to almost sublithographic dolostone. Bituminous or shaley partings are common in the upper part of the Goat Island. Bluish-grey and white chert nodules are abundant in some parts of Ontario. The chert bearing facies are often referred to as the 'Ancaster Chert Beds' and usually occur at the base of the Goat Island Member. The contact with the underlying Gasport member is sharp but conformable.

The thickness of the Goat Island Member is quite variable due to the development of an inter-reef Eramosa facies and because of the present-day erosion surface. The thickness may vary from 5.3 to 14 m (ODM, 1976; Vos, 1969) in the Niagara Region but it is thought to reach a maximum of 18 to 24 m.

Most quarry sections along the Escarpment expose the Goat Island Member. It has been used to produce a wide variety of crushed stone products for road-building and construction purposes including concrete stone, granular base coarse, armour stone, metallurgical stone, agricultural lime and some hot-laid asphaltic stone products. Vos (1969) notes that lateral lithological variations within the unit may prevent its use in some areas. Therefore, specific sites for extraction should be thoroughly tested before development of a quarry is contemplated in this material.

It is presently quarried primarily for the production of aggregate for road construction at Queenston, Walker Brothers and Vineland quarries. It was also previously mined by St. Catherines Crushed Stone Limited. Although the Goat Island Member is known to be quite cherty in many areas of Ontario, there has been no chert found in any of the quarries mentioned here (Hewitt and Vos, 1972).

Eramosa Member

The upper limit of the Goat Island Dolomite is arbitrarily drawn at the first appearance of dark brown to black bituminous material which is characteristic of this member. It is poorly exposed over most of the Niagara Region due to the nature of the present day erosion surface but it can be seen in Twenty Mile Creek and is known from borings in the Niagara Falls area.

This member consists of a medium to thin-bedded, dark brown to medium brownish grey, aphanitic to sugary, very finely crystalline dolostone with bituminous or shale partings. Vugs are reasonably common and may be filled with gypsum. Black chert nodules may also be present in varying sizes. Although shale beds at the base of this unit may not be widespread in the Niagara Region, they have been exposed at Vinemount Quarries near Stoney Creek to a maximum thickness of 5.2 m. This shaley unit has poor soundness and is unsatisfactory for concrete aggregate (Hewitt, 1960).

Because of the present day erosion surface, the thickness of this unit is observed to be rarely more than 3 to 3.7 m (ODM, 1976; Vos, 1969). It is thought to be about 9 m in average thickness although it may locally exceed 21 m in the Niagara Region (OGS, in print).

The Eramosa can have very high Magnesium Sulphate losses (MTC) and therefore may be unacceptable for several aggregate products in certain circumstances. In addition, lateral lithological variations with local development of a shaly facies make it necessary to thoroughly test dolomites of the Eramosa member before large-scale production is decided upon (Vos, 1969).

The Eramosa Member is currently being quarried by King Paving and Materials Ltd.

Guelph Formation

Overlying the Eramosa Member is a thin to thick-bedded, creamy buff, tan or brown, uniformly textured, aphanitic to finely crystalline, porous dolostone of the Guelph Formation. The lower boundary between the cherty dolostone of the Eramosa and the tan dolostone of the Guelph Formation is easily recognized.

Due to the fact that the whole section has never been exposed in the Niagara Region, no reliable estimate of thickness can be made in the area (although it has been found to be 30 to 60 m in other areas of Ontario).

Guelph dolomite is an important source of high purity dolomite for the manufacture of dolomitic lime in some parts of Ontario. Although this material is generally considered to be somewhat soft and porous to produce a good quality load-bearing aggregate, this varies from area to area and has been quarried at some places in Ontario for that purpose in the past (Vos, 1969; OGS, in print).

The Guelph Formation is covered by thick drift in most of the Niagara Region with the exception of relatively small areas near the contact between it and the Lockport Formation. Quality data regarding this Formation is also quite limited and therefore it has not been selected as a bedrock resource.

Salina Formation

A brown or grey, easily weathered, argillaceous dolostone and grey, calcareous shale containing abundant gypsum veins and lenses and evaporites overlies the Guelph Formation in some areas.

The thickness of this unit varies considerably but its maximum is about 115 m.

Bertie Formation

Previously referred to as the Bertie-Akron Formation, this unit extends in a narrow outcrop belt approximately east-west across the Niagara Region and forms the uppermost unit of the Silurian System in the Niagara Peninsula. The Bertie Formation consists of three separate subunits.

The lower 3.6 to 4.5 m consists of thick-bedded, medium to dark brown, aphanitic, bituminous dolostone. Overlying this is 2.4 to 3.4 m of grey, very argillaceous (weathers shaley) dolostone followed by 1.5 m of grey-brown, very finely crystalline, even textured dolostone. At the top of the unit are 2.1 to 3 m of irregularly, medium to thin-bedded, mottled brown dolostone (Telford and Tarrant, 1975).

Magnesium sulphate soundness results can be quite variable (MTC). Magnesium soundness tests on stockpiled Granular "A" produced by a quarry mining the Bertie Formation (among other Formations) showed that the material was quite good (losses 12 to 13 percent) for coarse concrete aggregate. Similar tests on washed screenings from the same quarry showed that soundness losses were quite variable (14 to 25 percent) and the material would be marginal for concrete sand (MTC). On the other hand, tests on screenings from another quarry in this area had values ranging from 8 to 14 percent which would be perfectly acceptable for fine concrete aggregate. It has also been found that Bertie dolostone can also have quite high absorption values (MTC).

The lower part of the Bertie can be used for concrete aggregates but because of its bitumen content, it requires extra washing to remove adhering fines. It's dark colour will not allow the rock to be used for exposed concrete (a white concrete is more aesthetically pleasing). The argillaceous section may also be unsuitable for some aggregate uses because of poor durability (OGS, in print).

The upper part of the Formation is well suited for concrete and load-bearing aggregate (OGS, in print).

In general, the Bertie Formation is suitable for a wide range of high-specification construction and road-building products including stone for concrete, hot-laid asphalt and granular road base, railway ballast and armour stone (OGS, in print).

This unit is currently being quarried in the Humberstone Quarry of Port Colborne Quarries Limited and at R.E. Law Crushed Stone Limited. R. E. Law quarries the Bertie Formation for road construction and concrete aggregate and has a Portland Cement plant on site (OGS, in print).

Bois Blanc Formation

A major disconformity separates the Bertie and Bois Blanc Formations. At the base of this Formation is a medium to coarse-grained, greenish grey or white, calcareous, quartz sandstone with interbeds of green glauconitic sandstone, sandy limestone, dolostone and brown chert. A maximum of 1.2 m of this lithology has been identified in the Niagara Region and represents the Springvale Sandstone unit.

The remainder of the Bois Blanc Formation consists of medium to thin-bedded, irregularly laminated, greenish grey to light grey brown, argillaceous or cleanly bioclastic cherty limestone with shale partings and minor dolostone.

The total thickness of the Bois Blanc Formation varies from 3.5 m in the Ridgemount area to about 4.2 m in the Port Colborne area (Telford and Terrant, 1974).

The Bois Blanc Formation has been quarried for crushed stone, rubble and rip-rap but the high chert content often makes the material unsuitable for use as concrete aggregate, granular base coarse, hot-laid asphalt and railway ballast (OGS, in print).

Ridgemount Quarries are currently quarrying the Bois Blanc Formation and concrete aggregate has been obtained from the lower lift (Hewitt and Vos, 1972). Magnesium sulphate losses on washed screenings from this quarry varied from 11 to 14 percent showing that this material can be acceptable for concrete in certain circumstances. An asphalt plant was once located at the Quarry. R.E. Law Crushed Stone is also quarrying approximately 8.5 m of the Bois Blanc Formation (Hewitt and Vos, 1972; OGS, in print).

In some places, the lower Bois Blanc Formation is nominally a limestone. For example, at Port Colborne Quarries, the silica content of 2.7 m of the lower part of the Bois Blanc Formation was found to be approximately 68 percent (Hewitt and Vos, 1972); the silica occurring as layers and nodules of chert. Although this may be true, the upper part of the Bois Blanc has been blended with shaley dolomite of the Bertie Formation to produce a perfectly acceptable granular "B" (Hewitt and Vos, 1972).

Onondaga Formation

Disconformably overyling the Bois Blanc Formation is the Middle Devonian Onondaga Formation consisting of three distinct members; the Edgecliffe, Clarence and Moorehouse.

The Onondaga Formation is generally considered to be 'soft' but it has been quarried for granular base course ("A" and "B"), railroad ballast and various sizes of clear crushed stone. It has been used as a raw material in cement manufacture but its chert content makes the material unsuitable for concrete aggregate (OGS, in print; Telford and Tarrant, 1974).

Edgecliffe Member

The limestones of this member exhibit great diversity but can be grouped into three main facies types.

The most widespread is the biostromal facies consisting of medium-bedded, fine to medium-grained, dark grey (weathering light grey or buff), fossiliferous, bioclastic limestone containing irregular thin beds or nodules of black chert.

The reefal limestones are massive, light grey, very porous, and coarse-grained. The remaining limestones are irregularly-bedded, grey, medium to coarse-grained, very fossiliferous and contain abundant black chert nodules. Thin beds and partings of greenish shale are commonly associated with the reefs.

The combined thickness of the biostromal and reefal-biohermal facies varies considerably but has been measured at 8.4 m at the Ridgemount Quarries.

The third major facies at the lower part of the member is developed only in the Port Colborne area. It essentially consists of medium-bedded (weathering to thin beds) of dark greenish-grey, very argillaceous, fossiliferous limestone with rare chert. The limestones readily weathers into a soft shaley material. This third facies unit is about 3 m in thickness (Telford and Tarrant, 1974).

Clarence Member

Conformably overlying the Edgecliffe Member is a massive-bedded, dark grey-brown, fine-grained, poorly to non-fossiliferous, extremely cherty limestone. The chert is dark grey or brown and often opaline, occurring as thin beds and irregular nodules which may constitute over 50 percent of the rock.

Although neither the upper and lower contacts are both exposed together so that a thickness can be accurately determined, the thickness of this member has been estimated to be about 8m (Telford and Tarrant, 1974).

Moorehouse Member

The Moorehouse Member is the uppermost unit of the Onondaga Formation. It essentially consists of a medium-bedded, brown, fine to medium-grained, fossiliferous, variably cherty limestone. The chert is dark grey or brown and occurs as thin beds or rounded nodules.

The thickness of this unit has been estimated to be approximately 8 m (Telford and Tarrant, 1974).

APPENDIX VIII

ALTERNATIVE LAND-BASED SOURCES OF SAND AND GRAVEL IN NIAGARA: AN INVENTORY

APPENDIX VIII

ALTERNATIVE LAND-BASED SOURCES OF SAND AND GRAVEL IN NIAGARA: AN INVENTORY

This section represents an inventory of the land-based sources of sand and gravel in the Niagara Region outside of the Fonthill Kame. Both licensed and unlicensed sources of supply are included. These deposits have been mapped on Drawing No. 2 found in the back pocket of this Report. They have been classified according to their "primary", "secondary" or "tertiary" level of significance on a Regional basis. They are described and assessed according to the areas in which they are situated. The six areas include:

1) Grimsby, Lincoln and West Lincoln

2) St. Catharines and Niagara-on-the-Lake

3) Niagara Falls

4) Welland and Thorold

5) Wainfleet

6) Port Colborne and Fort Erie

Data on the amounts of crushable material available in each deposit were not available in all cases.

The primary source of information on land-based deposits was the Ontario Ministry of Natural Resources.

1) Grimsby, Lincoln and West Lincoln

Grimsby and Lincoln have extensive but shallow deposits of sand particularly near the Lake Ontario shoreline. West Lincoln, on the other hand, has only two known deposits which are quite small. The Ministry of Natural Resources has estimated supplies of about 129 million tonnes. However, all of the resources that have been identified are considered to be of "tertiary significance" only. This is due to factors such as the fine-grained nature of the resources for most aggregate uses, shallowness of the deposits, and their availability for extractive development. Also, most of these resource areas contain objectionable quantities of clay and/or silt fines that are unsuitable in terms of use for construction-grade aggregates.

From a quality point of view, certain deposits may be suitable for some local extraction of low specification construction aggregates. Geologically, they are the glacial Lake Iroquois beach and bar deposits located along the north side of

Regional Road #81. Generally, they are composed of gravelly sand and gravel about 1 m to 3 m thick. Some wayside pit activity may be possible.

For the most part, these low-quality deposits in the Grimsby and Lincoln areas are also constrained by three main factors:

- unique agricultural lands for tender fruit and grape production
- urban development
- the Niagara Escarpment

The deposits in West Lincoln are extremely small and shallow and are too fine-grained for most construction uses.

2) St. Catharines and Niagara-on-the-Lake

The Ministry of Natural Resources has identified extensive but shallow deposits of sand and gravel resources throughout St. Catharines and Niagara-on-the-Lake, particularly in areas close to the Lake Ontario and Niagara River shorelines. About 202 million tonnes of sand are estimated, however, all of these resources are considered to be of "tertiary significance" only.

The deposits range between 1 m and 6 m in thickness and geologically are glaciolacustrine beach or plain deposits. Most of these deposits contain objectionable quantities of clay and/or silt fines and are therefore unsuitable for construction-grade aggregates. They contain less than 35% crushable aggregate material.

The thickest of the deposits is the Homer Bar which is a glacial Lake Iroquois beach and bar deposit situated in the City of St. Catharines. This deposit consists of gravelly sand and gravel and extends to a depth of about 8 m. Early in 1980, the Ministry of Natural Resouces has identified this bar as the only major source of sand and gravel on the Iroquois Plain, and estimated reserves at about 7.3 million tonnes. However, since most of this deposit is covered by urban development (i.e. downtown St. Catharines), future extraction in this area is highly unlikely.

From a quality point of view, certain deposits in this area of the Region may be suitable for some local extraction for low specification construction aggregates. Geologically, they are glacial Lake Iroquois beach and bar deposits scattered in several locations such as in the western part of St. Catharines, near the Niagara District Airport southwest of Virgil, and south of the old Town of Niagara-on-the-Lake. Some small-scale extraction, probably in the form of wayside pits, may be possible according to the Ministry.

Like Grimsby and Lincoln, the deposits throughout both St. Catharines and Niagara-on-the-Lake are heavily constrained by factors such as:

- unique agricultural lands for tender fruit and grape production
- urban development

3) Niagara Falls

The sand and gravel deposits of Niagara Falls are found in three main locations:

i) Southwest Niagara Falls, straddling the Welland boundary

ii) Central Niagara Falls

iii) St. David's

The Ministry of Natural Resources has estimated that the total sand and gravel resource, primarily in the St. David's area of Niagara Falls, amounts to about 14 million tonnes. However, most of these resources are constrained primarily by urban development and only 2 million tonnes in unlicensed areas in the St. David's area might be available for extraction purposes. The Ministry considers the St. David's resource as an area of "secondary significance". All other resource areas are considered to be of "tertiary significance" only.

i) Southwest Niagara Falls

The deposits in the southwest part of the City are described in the Welland/Thorold section.

ii) Central Niagara Falls

There is a cluster of deposits located in the Stamford and Lundy's Lane areas of the City. Geologically, they are described as Lake Warren and younger pre-Iroquois deposits of gravelly sand that are greater than 2 m in depth. The amount of this material is small and potential uses for it are limited.

The major constraint to their future extractive development is that most of the resource areas are covered by urban development and include among other developments a large cemetery.

iii) St. David's

The largest deposit in Niagara Falls, and one that is probably the most complex geologically, is the St. David's sand and gravel deposit situated on top of the Niagara Escarpment. It is sometimes referred to as the St. David's Buried Gorge. This deposit is a well-stratified, well-sorted, ice-contact glaciolacustrine delta at the head of the St. David's re-entrant valley.

A great deal of extraction has occurred in the past, particularly for the coarser materials which were used primarily for granular base and subbase materials. Today, however, only a small amount of extractive activity occurs. According to the Ministry of Natural Resources, only fine reddish sands with very little gravel predominates in this area, particularly in licensed properties. Therefore, the range of products available is significantly reduced. The main product sold presently is fill material for road and building construction. According to the Ministry and a local aggregate producer, some coarser materials like granular "C" or even concrete sand may be available in some locations but at great depths in the deposit.

These materials were probably laid down in scattered fluvioglacial channels throughout the deposit. However, due to both the variable nature of the deposit and the depths required for extraction, the Ministry believes that it is unlikely that higher quality fine aggregates like concrete sand or winter sand will be produced in the future. Until extensive geological testing is conducted, there is no way of accurately determining exact quantities of this type of material.

There are four licensed sand pits in the area which occupy 73.9 Ha of land. In 1984, they accounted for a little more than 6% (ie. 36,000 tonnes) of the Region's total sand and gravel production (ie. 576,000 tonnes). Since the deposits are easily extracted and require little processing for the end use required (ie. backfill), the product is relatively inexpensive compared to other types of sand and gravel products.

In the early 1980's, the Ministry of Natural Resources estimated that the remaining reserves within all licensed and unlicensed sources in St. David's were about 7.3 million tonnes. It was recognized, at that time, that existing urban development was a major constraint to the development of the resource area, particularly in the south. Since that time, the Ministry has conducted some geological studies in this area and has evaluated some test reports prepared by a local producer. The Ministry now estimates that only 2.2 million tonnes of material may be available in unlicensed and undeveloped areas in St. David's. However, this estimate does not include possible supplies in licensed sources and in undeveloped areas inside the Niagara Falls urban area boundary. It is the Ministry's opinion that most of this material is suitable only for fill. They report that the fines content is very high (ie. up to 40%) and does not permit economic production of higher specification aggregates.

Recent discussions with local aggregate producers in St. David's reveal that licensed reserves are estimated at about 0.5 million tonnes. Therefore, the total sand and gravel resource base in licensed and unlicensed areas in St. David's outside the Niagara Falls urban area, is estimated at 2.7 million tonnes.

Finally, it is noted that one 11.1 Hectare licensed pit area lies completely outside the identified St. David's deposit. This peculiarity may be explained by the uncertainty of the resource area boundaries in this location. The Ministry noted, however, that this small area is not a granular source and may contain only fine sand and loam.

4) Welland, Thorold and Southwest Niagara Falls

The Ministry of Natural Resources has identified a cluster of small sand and gravel deposits situated generally in the southeastern parts of Thorold and Welland, and in the southwestern part of Niagara Falls. They estimate that the total sand and gravel resource here amounts to about 26 million tonnes. Many of these deposits are shallow glaciolacustrine beach or plain deposits of fine sand

and gravel. For example, the deposit lying at the edge of the Welland urban area just north of East Main Street may contain about 74,400 tonnes of sand and gravel. There is some evidence to suggest that deleterious shale and siltstone fragments may be present (siltstone and shale fragments need to be removed before an aggregate deposit can be used in higher specification-type products like concrete sand or asphalt sand for construction purposes). Due to quantity, quality and availability problems, the Ministry believes that most of these deposits are of "tertiary significance only".

Three deposits near or on the Welland/Niagara Falls border are considered by the Ministry as areas of "secondary significance". These deposits are the sites of former proglacial lake beaches which occur on moraine ridges composed of fine-grained till protruding through a thick blanket of proglacial lake clays. The linear glaciolacustrine beach deposits generally are more than 6 m thick and consist of more than 35% crushable aggregate. They are estimated to contain about 7.3 million tons of coarse, gravelly material.

In the opinion of the Ministry, the probability of obtaining crushable aggregate is relatively low since the beach material was derived by wave-washing of the fine-grained till. Some of the products that might be available include granular "B", granular "C" and fill. The Ministry notes that some granular "A" and concrete sand could be produced if processing facilities were available. However, the size of the deposits discourages their development on a commercial-use basis. It is more likely that the deposits will be used for wayside pit activity primarily for local road needs.

The features described above, have been subject to a great deal of extractive activity in the form of small wayside pits. However, constraints to the further development of these resources for future extraction include houses, a railway line and a cemetery.

5) Wainfleet

From a general perspective, the Township has a very limited supply of granular resources. The existing deposits are quite shallow, fine-grained and fairly small in area. They may be capable of supplying small amounts of low specification construction aggregates for local use. The Ministry of Natural Resources considers all of the Township's identified resources to be of "secondary" or "tertiary significance".

The Ministry has estimated that the total tonnage of all sand and gravel resources in Wainfleet is about 28 million tonnes. However, due to a variety of constraints present, only 8 million tonnes may be available for development. The deposits of "secondary significance" include:

i) The inland dunes on the west side of Wainfleet near the Haldimand-Norfolk boundary

ii) The dunes along the Lake Erie shoreline

iii) The beach/bar and till deposits surrounding the Port Colborne Airfield

i) Inland Dunes

The inland dunes, that are parabolic in shape, are glaciolacustrine deltaic sand deposits. These dunes tend to be finer and more loamy than the shoreline dunes. They were deposited after the glacial period through wind erosion and transport. The dunes consist of uniform, fine-grained sand and may be used for some low specification construction products like fill, granular "C" and blending sand. Although no pits have been developed in these dunes, similar deposits are used for aggregates in the neighbouring Town of Dunnville.

ii) Shoreline Dunes

A narrow discontinuous strip of more recent sand dunes is found along the Lake Erie shoreline behind the beach deposits. They were formed by the dual processes of eastward moving, longshore transport of sand by Lake Erie waters, and then subsequently, by westerly winds which moved and molded the beach sands. Although these dunes vary in height, they are not as high or as well-developed as those in Port Colborne and Wainfleet. Dune sand is uniformly fine to medium-grained and is rich in quartz minerals.

In the past, some of this material was extracted mainly for blending sand for asphalt production. Dune sand also may be suitable for metal casting, filtration and fill purposes. Extensive cottage development and environmental considerations are major constraints to future development. Dunes also are sensitive to wind erosion once their protective cover of vegetation is removed.

iii) Inland Beach/Bar and Till Deposits

The four small inland deposits that are situated around the Port Colborne Airfield are glaciolacustrine beach/offshore bar deposits of sand and fine gravel. They are situated on top of till ridges or bedrock rises and are about 2 m thick. Reserves in the largest deposit, just north of Burnaby, are estimated at about 2 million tonnes. As wayside operations, they may be capable of supplying small quantities of aggregate, including some granular base coarse products, for local use. The Ministry also noted that there may be some potential to produce concrete sand. However, the size of the deposits discourages their development on a commercial basis. Other constraints to their development include houses, a church, cemeteries and a greenhouse.

6) Port Colborne and Fort Erie

In Port Colborne and Fort Erie there are two main types of deposits:

i) inland deposits of till overlain by beach/bar materials

ii) sand dunes along the Lake Erie shoreline

The Ministry has estimated that the total tonnage of all sand and gravel resources in Port Colborne and Fort Erie is about 118 million tonnes. However, due to a variety of constraints present, only 4 million tonnes of material may be available for development outside of licensed areas.

Generally, these more important deposits contain small amounts of glaciolacustrine beach sand and gravel. In the opinion of the Ministry, they are probably only suitable for local road maintenance aggregate and other low-specification uses.

i) Inland Beach / Offshore Bar Deposits

The inland deposits were formed during the last period of glaciation when a layer of glacial till (ie. Halton Till) was deposited over bedrock. Later this material was buried by younger glaciolacustrine deposits. Two major till moraines about 8 m high, are exposed along the Onondaga Escarpment.

1) The Crystal Beach Moraine is a long, narrow ridge extending more than 5 kilometres from Sherkston to Crystal Beach; and

2) The Fort Erie Moraine which begins inside the Fort Erie urban area and extends west to the Onondaga Escarpment.

This till material has a variable silt to clayey silt composition with a low stone content. Generally, the material is unsuitable for use as a load-bearing aggregate.

In addition to the till deposits, there are numerous small beach and deltaic sand and gravel deposits scattered throughout the two municipalities. These deposits consist of less than 5 m of stratified coarse sand and minor gravel. They contain small possible resources of sand and gravel for low-specification load-bearing aggregates such as granular base-coarse. Most of the deposits like the Crystal Beach Moraine are heavily constrained by competing uses such as residential development; and in some cases, commercial and recreational uses are present. Thus, very little of the material is available for possible extraction.

One deposit in Fort Erie and three others in Port Colborne have been selected by the Ministry as areas of "primary significance". Generally, they consist of glaciolacustrine beach / offshore bar deposits of sand and gravel and may contain about 4 million tonnes of material. Some of the products that could be produced include granular "B", granular "C" and fill. The Ministry notes that some granular "A" and concrete sand could be produced if processing facilities were available. However, the size of the deposits discourages their development on a commercial basis.

The deposit in Fort Erie is located northeast of Ridgeway on top of the Onondaga Escarpment and is less than 6 m in height. This broad, indistinct ridge-like deposit is about 45 Ha in size and is estimated to contain about 2 million tonnes of material. The material may be suitable for a range of road-building and construction aggregates.

Constraints to the development of this deposit include houses in the area, a power transmission line, a cemetery and a historical burial vault / park area.

The deposit also has been identified by the Outdoor Recreation Group of the Ministry of Natural Resources as an Area of Natural and Scientific interest (A.N.S.I.). However, the Ministry does not believe that such designation represents a major constraint to the development of the resource here. It is their view that small-scale extractive development in this deposit could increase its scientific and interpretive value by exposing underlying formations.

The three deposits on the east side of Port Colborne near the Humberstone Marsh are long, linear ridges that are less than 5 m high. They occupy about 52 Ha and consist of clean, well-sorted coarse sand and minor gravel. Possible resources in these deposits have been estimated at 2 million tonnes.

The major constraints to the development of these resources include houses in the area and an intensive livestock operation.

ii) Shoreline Dunes

The beach deposits and dunes that line the Lake Erie shore were formed more recently than the other deposits described above. The beaches consist of well-sorted sand and minor gravel while the associated dunes to the rear consist of uniform fine to medium-grained sand relatively rich in quartz minerals. The dune deposits were derived from onshore wind erosion of the beach deposits. They are much higher and more developed than dunes in the western part of the Niagara Region. They range in height 9 to 27 m. Dune sand is suitable only for a limited range of products including flux sand, fill material, and possibly as asphaltic blending sand.

Commercial sand and gravel extraction in this part of the Region occurs in only two locations, those being within the dune deposits in the Sherkston-Point Abino area. Extraction has been a relatively low volume activity due to the small available resource base and the low quality of the material. In 1984, sand and gravel production here accounted for less than 1 percent (ie. 4200 tonnes) of the Region's total production (ie. 576,000 tonnes).

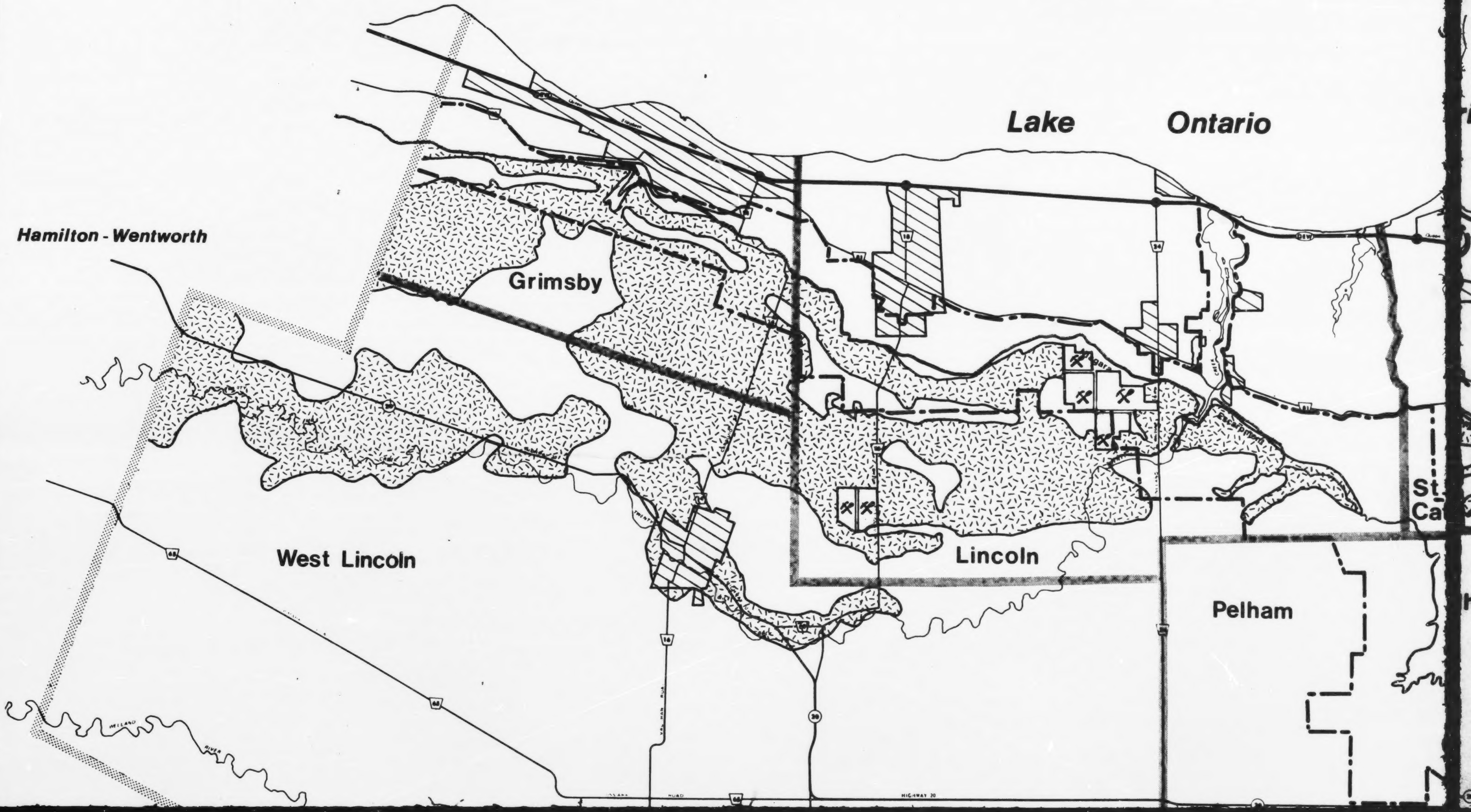
Although some dune areas along the shoreline may be free of development, environmental considerations may limit extraction. For example, the forested dunes in the Sherkston and Point Abino areas have been considered by many to be unique and fragile features of Ontario. If their protective vegetation was to be removed by extraction, for example, they would become quite sensitive to wind erosion.

Other major constraints to their development include extensive lakeshore residential development, cemeteries, railway lines, industrial uses, trailer parks, and public as well as private recreational areas.

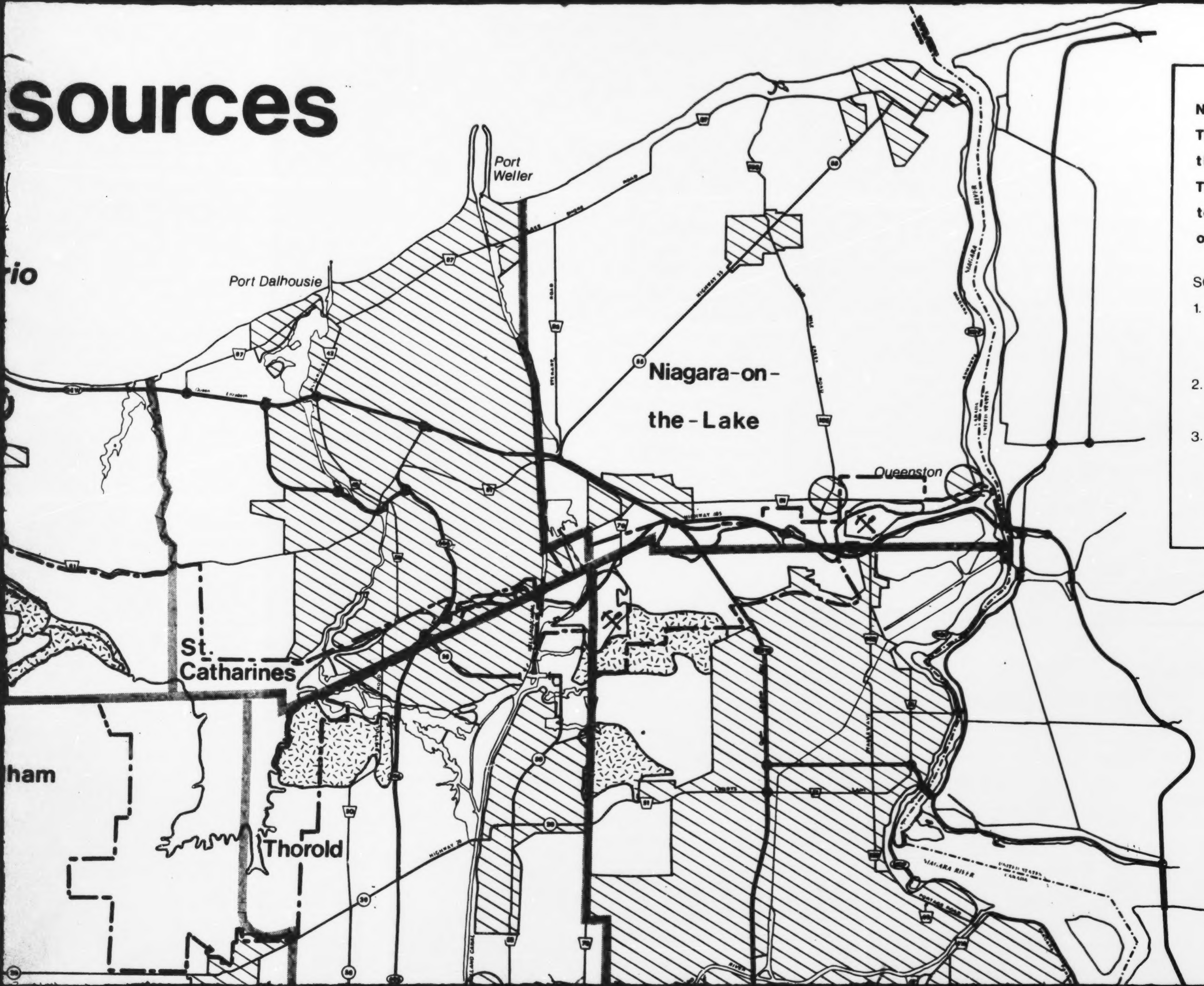
The material from two pits, Eberly Trucking Ltd. and Hard Rock Paving Co. Limited, has been sold for winter sand, backfill, filtering, metal-casting, asphaltic blending and local road maintenance. Today, however, it is suitable only for backfill, metal-casting and some recreational purposes. About 51 hectares of land are currently licensed. However, licensed reserves from these pits are estimated to be between only 27,000 to 36,000 tonnes. Due to wind erosion of nearby beach deposits and other shore dunes, the supply in one pit may be replenishing itself to some degree.

Drawing No. 1

Inventory of Bedrock Resour


Lake
Ontario
Hamilton - Wentworth
Grimsby
West Lincoln
Lincoln
Pelham
St.
Ca
Escarpment
Welland
River
Highway 20
Road

sources

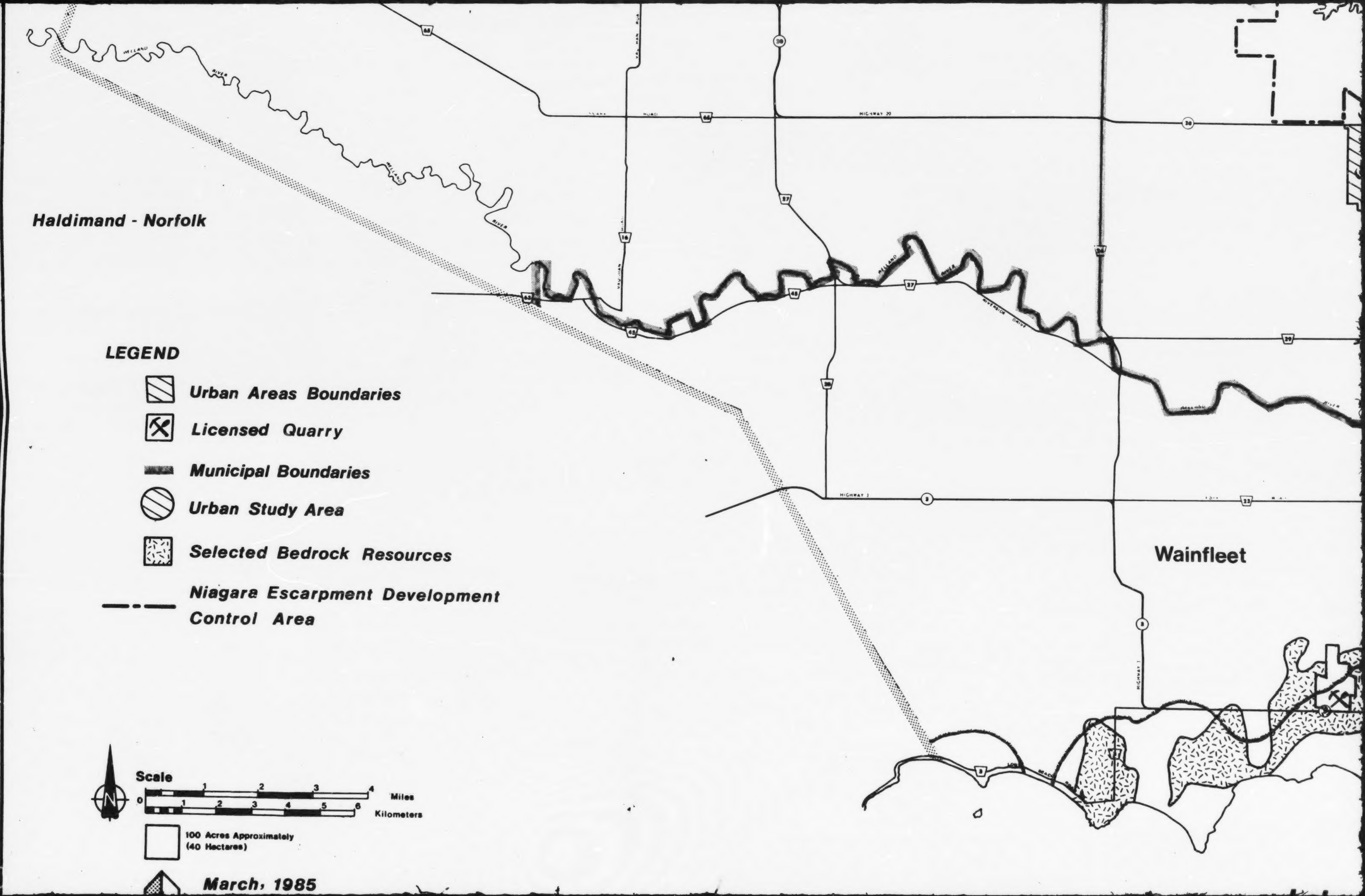

rio
Port Weller
Port Dalhousie
Niagara-on-the-Lake
Queenston
St. Catharines
Thorold
ham
Niagara River
Highway 55
Highway 20
United States
Canada

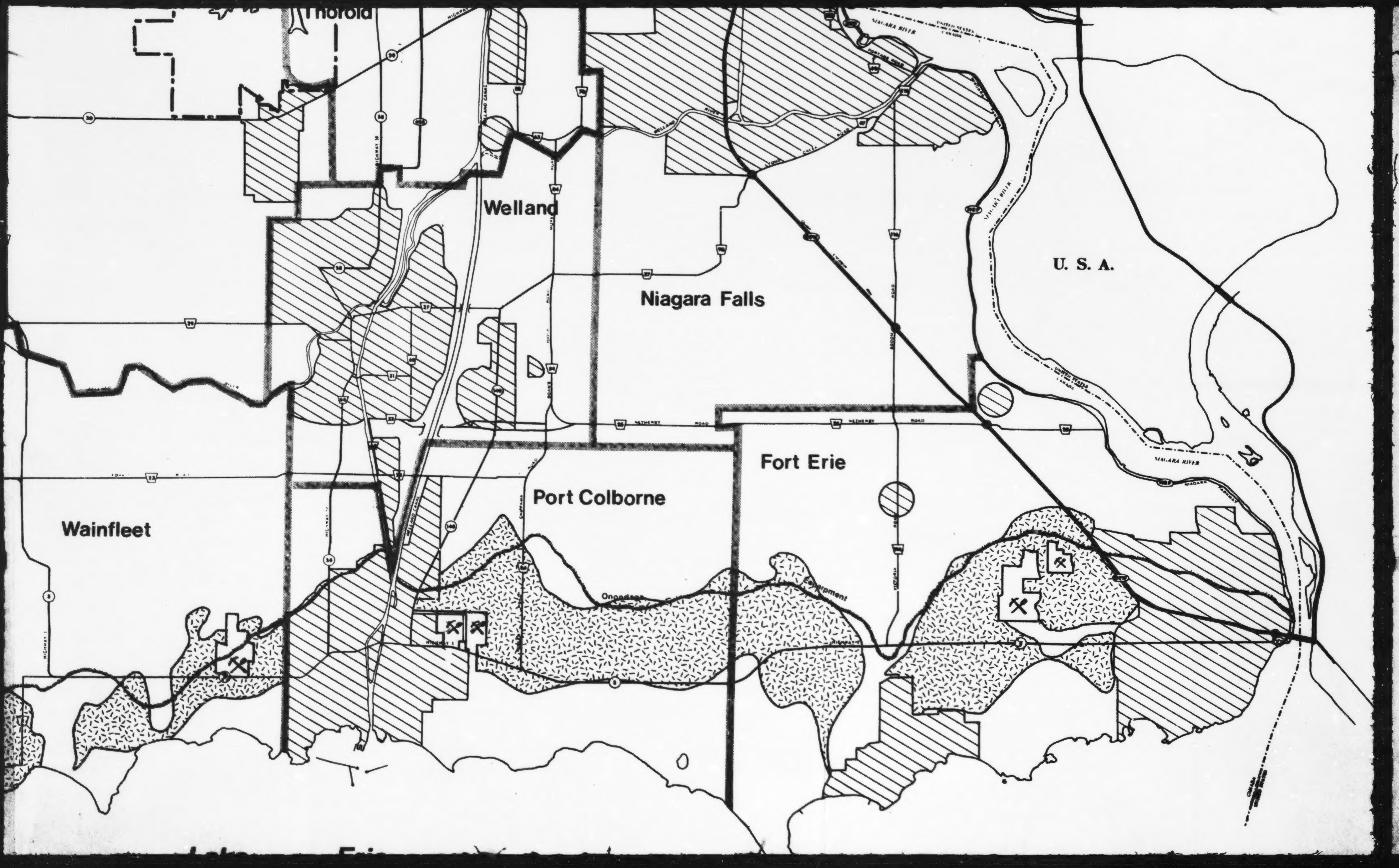
NOTE:

The selected bedrock resources shown on this map are for inventory purposes only. This map should not be interpreted to mean that extraction either is desirable or will be permitted

SOURCES

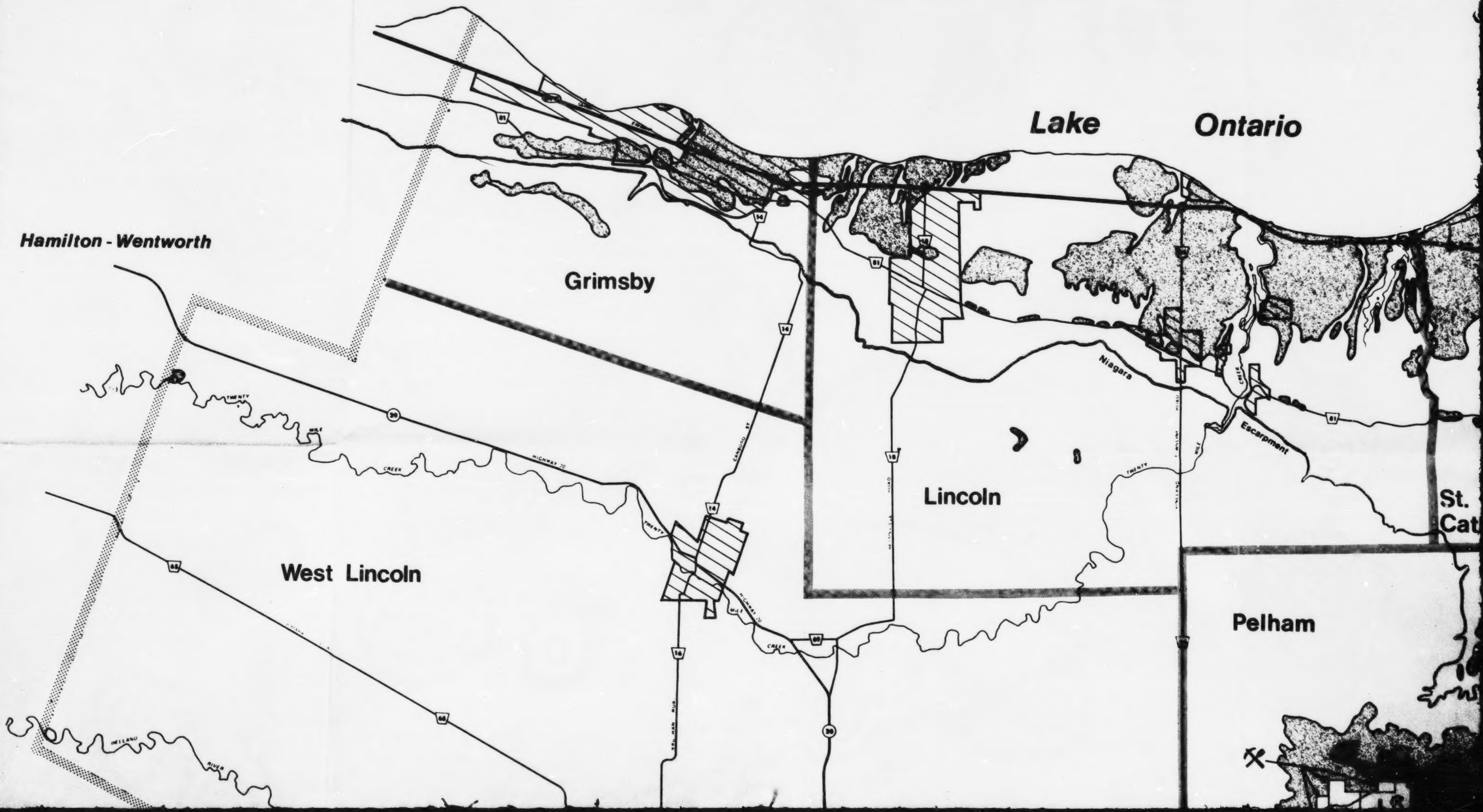
1. Bedrock resources derived from published and preliminary maps of the Ministry of Natural Resources
2. Licensed areas derived from site plans provided by the Ministry of Natural Resources
3. Selected bedrock resources exclude those resources within the Niagara Escarpment Development Control Area and all urban area boundaries


Haldimand - Norfolk
Wainfleet
LEGEND
Urban Areas Boundaries
Licensed Quarry
Municipal Boundaries
Urban Study Area
Selected Bedrock Resources
Niagara Escarpment Development Control Area
Scale
0 1 2 3 4 Miles
0 1 2 3 4 5 6 Kilometers
100 Acres Approximately (40 Hectares)
N
March, 1985
Welland River
Highway 20
Highway 3
Riverside Drive
Highway 3

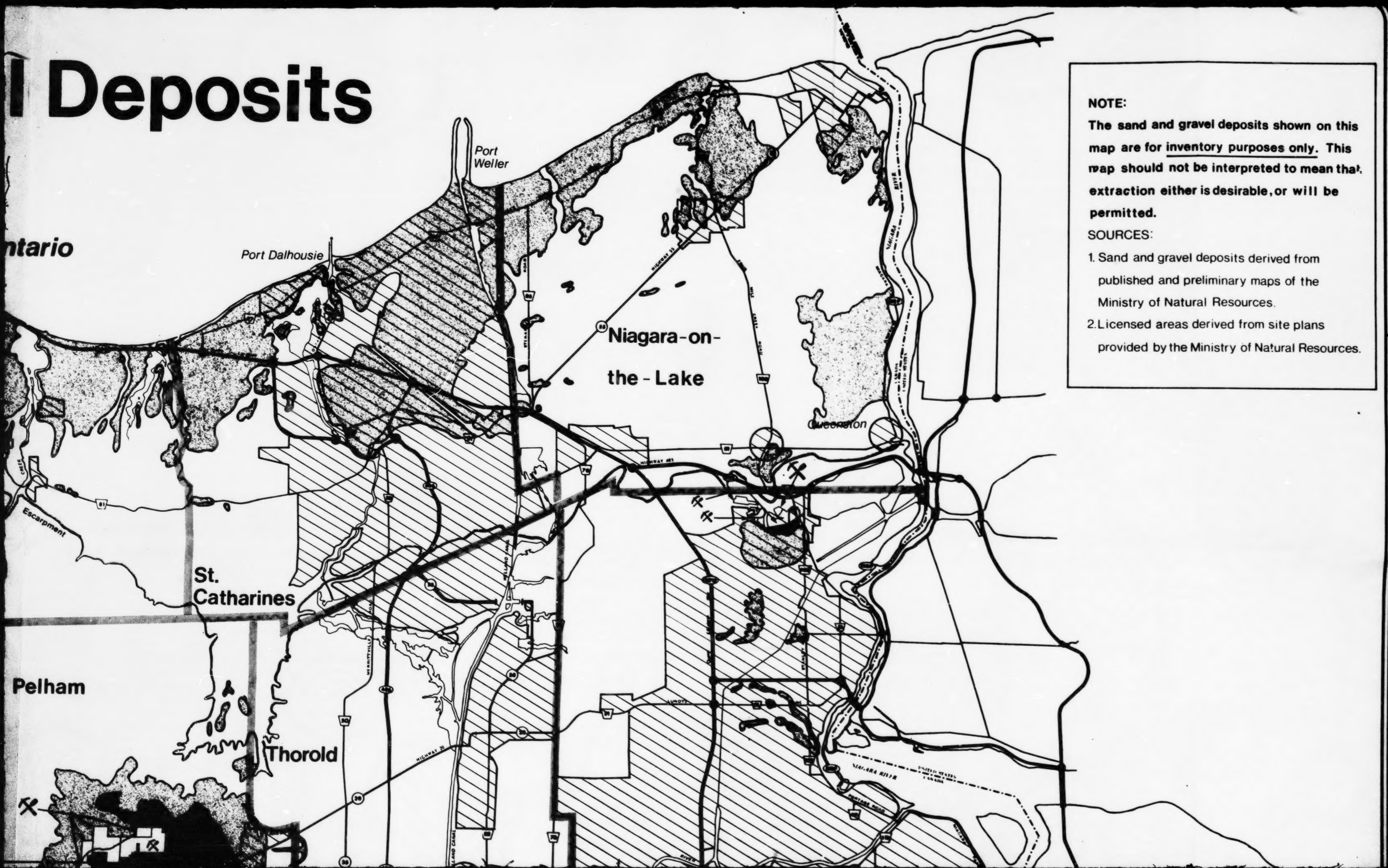

Thorold
Welland
Niagara Falls
U. S. A.
Niagara River
Netherby Road
Fort Erie
Port Colborne
Wainfleet
Onondaga
Escarpment
Highway 3
Welland Canal
Lake
Erie

Drawing No. 2

Inventory of Sand and Gravel Depo


Lake Ontario
Hamilton - Wentworth
Grimsby
Lincoln
West Lincoln
Pelham
St. Cat
Niagara Escarpment
Twenty Mile Creek
Highway 20
Welland River
81
20
14
18
65

l Deposits

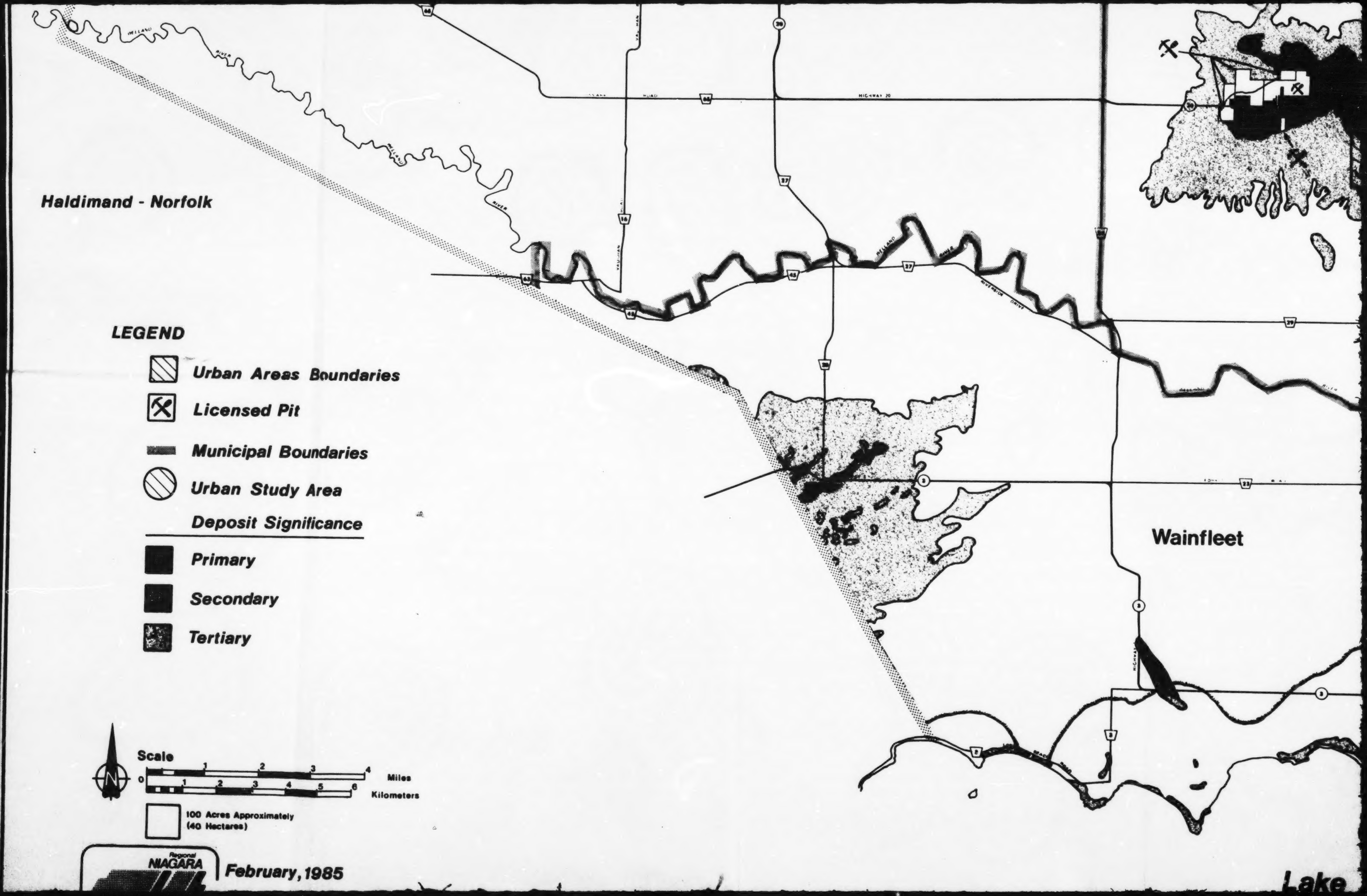

ntario
Port Weller
Port Dalhousie
Niagara-on-the-Lake
Queenston
St. Catharines
Pelham
Thorold
Escarpment
HIGHWAY 55
HIGHWAY 405
HIGHWAY 20
NIAGARA RIVER
UNITED STATES
CANADA

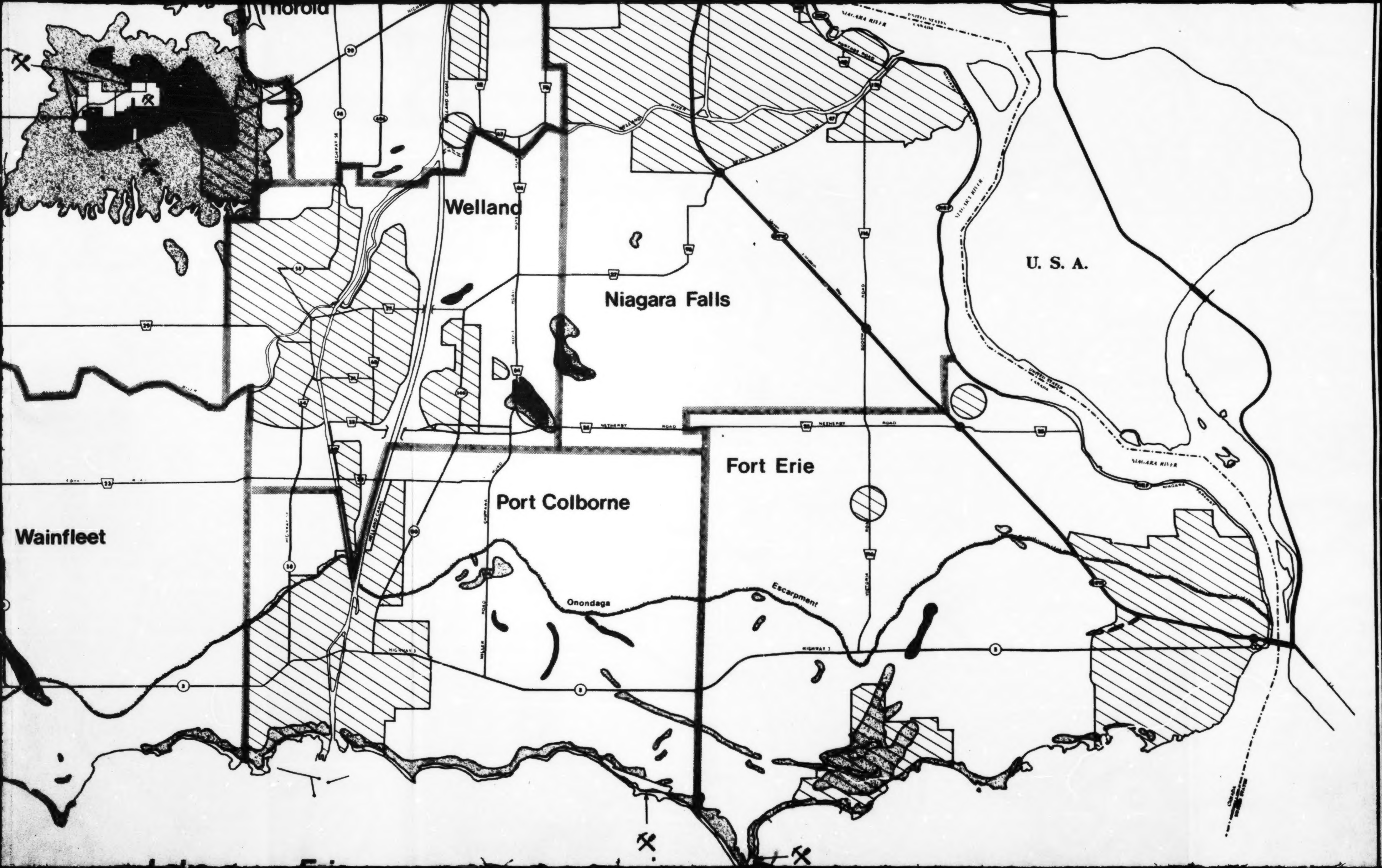
NOTE:

The sand and gravel deposits shown on this map are for inventory purposes only. This map should not be interpreted to mean that extraction either is desirable, or will be permitted.

SOURCES:

1. Sand and gravel deposits derived from published and preliminary maps of the Ministry of Natural Resources.
2. Licensed areas derived from site plans provided by the Ministry of Natural Resources.


Haldimand - Norfolk
Wainfleet
Lake
Welland River
Highway 20
Riverside Drive
LEGEND
▨ Urban Areas Boundaries
⚒ Licensed Pit
Municipal Boundaries
Urban Study Area
Deposit Significance
■ Primary
■ Secondary
▨ Tertiary
Scale
0 1 2 3 4 Miles
0 1 2 3 4 5 6 Kilometers
100 Acres Approximately (40 Hectares)
Regional NIAGARA
February, 1985


Thorold
Welland
Niagara Falls
U. S. A.
Fort Erie
Port Colborne
Wainfleet
Onondaga
Escarpment
Niagara River
Welland River
Welland Canal
Netherby Road
Highway 3
United States
Canada